The International Passamaquoddy TIDAL POWER PROJECT and UPPER SAINT JOHN RIVER Hydroelectric Power Development

REPORT to
President John F. Kennedy

Stewart L. Udall, Secretary
Department of the Interior
July 1963

The International Passamaquoddy Tidal Power Project
And
Upper Saint John River Hydroelectric Power Development

Report to President John F. Kennedy

In Response to Letter
of May 20, 1961

Stewart L. Udall
Secretary of the Interior
July 1963

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON 25, D. C.

July 1, 1963

Dear Mr. President:

This is my reply to your letter of May 20, 1961, asking this Department to review the International Joint Commission's report on the International Passamaquoddy Tidal Project and the Upper Saint John River Hydroelectric Power Development.

You requested that I advise you concerning the changes in fuel, engineering and financial costs which might result in making the project economically feasible. After exhaustive review and study made in close collaboration with the U. S. Army Corps of Engineers, utilizing information on load and resource data furnished by the Federal Power Commission, and the technical know-how available from the bureaus within this Department, I am transmitting to you the report of our findings. I am also transmitting the report of the Secretary of the Army and the accompanying review by the Chief of Engineers commenting on the International Joint Commission report which have been fully coordinated with this Department.

I have determined that the development of the Passamaquoddy Tidal Project and the Upper Saint John River is both desirable and economically feasible. The plan envisions a tidal power development at Passamaquoddy Bay and a hydroelectric powerplant on the Upper Saint John River which would provide 1,250,000 kilowatts of dependable capacity, of which 1,000,000 kilowatts would be peaking capacity and 250,000 kilowatts of capacity which would meet the local area loads. You will be pleased to note that this proposed plan will preserve in its entirety the free-flowing nature of the Allagash River and its superb recreational values.

The Department's proposal is feasible from an engineering and economic viewpoint. The benefit-cost ratio is 1.27 to 1.00 based on current United States' project feasibility standards and using an interest rate of 2 7/8 percent with power repayment within 50 years after each unit becomes revenue-producing.

We recognize that suitable arrangements will have to be made with the Canadian Government for the United States to construct the Passamaquoddy Tidal Project and to work out an equitable sharing of the downstream benefits from power development of the Saint John River in Canada.

In view of the extensive previous studies made on this project dating back to 1922 and the opportunity which still exists for additional engineering work in advance of construction, I recommend that this report be used as the basis for early authorization of the International Passamaquoddy Tidal Power Project and the storage and hydroelectric development on the Upper Saint John River by the U. S. Army Corps of Engineers and the marketing of the power by the Department of the Interior.

I also recommend that you request the Secretary of State to immediately initiate negotiations with the Government of Canada, looking toward a satisfactory arrangement for the sharing of the power and flood control benefits of the Saint John River in Canada and the development of the Passamaquoddy Tidal Power Project by the United States.

Respectfully yours,

Stewart L Udall

Secretary of the Interior

The President
The White House
Washington, D. C.

Enclosures

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON 25, D. C.

July 1, 1963

Memorandum

To: Secretary of the Interior

From: Passamaquoddy-Saint John River Study Committee

Subject: The International Passamaquoddy Tidal Power Project and the Upper Saint John River Hydroelectric Power Development

We herewith submit our final report on the International Passamaquoddy Tidal Power Project and Upper Saint John River Hydroelectric Power Development in accordance with your direction.

This report has been prepared under the general supervision of Assistant Secretary Kenneth Holum, Water and Power Development, and under the personal supervision of Under Secretary James K. Carr. This work has been done in response to the President's request of May 20, 1961, in which the Department of the Interior was asked to review the International Joint Commission report and to advise the President as to what changes in fuel, engineering and financing costs might result in making the project economically feasible. It was also requested that the President be advised as to the hydroelectric power development on the Upper Saint John River and other matters relating to the International Joint Commission report.

Morgan D. Dubrow

Morgan D. Dubrow, Chairman

Knoland J. Plucknett

Knoland J. Plucknett

Chas. W. Leavy

Charles W. Leavy

Mark Abelson

Mark Abelson

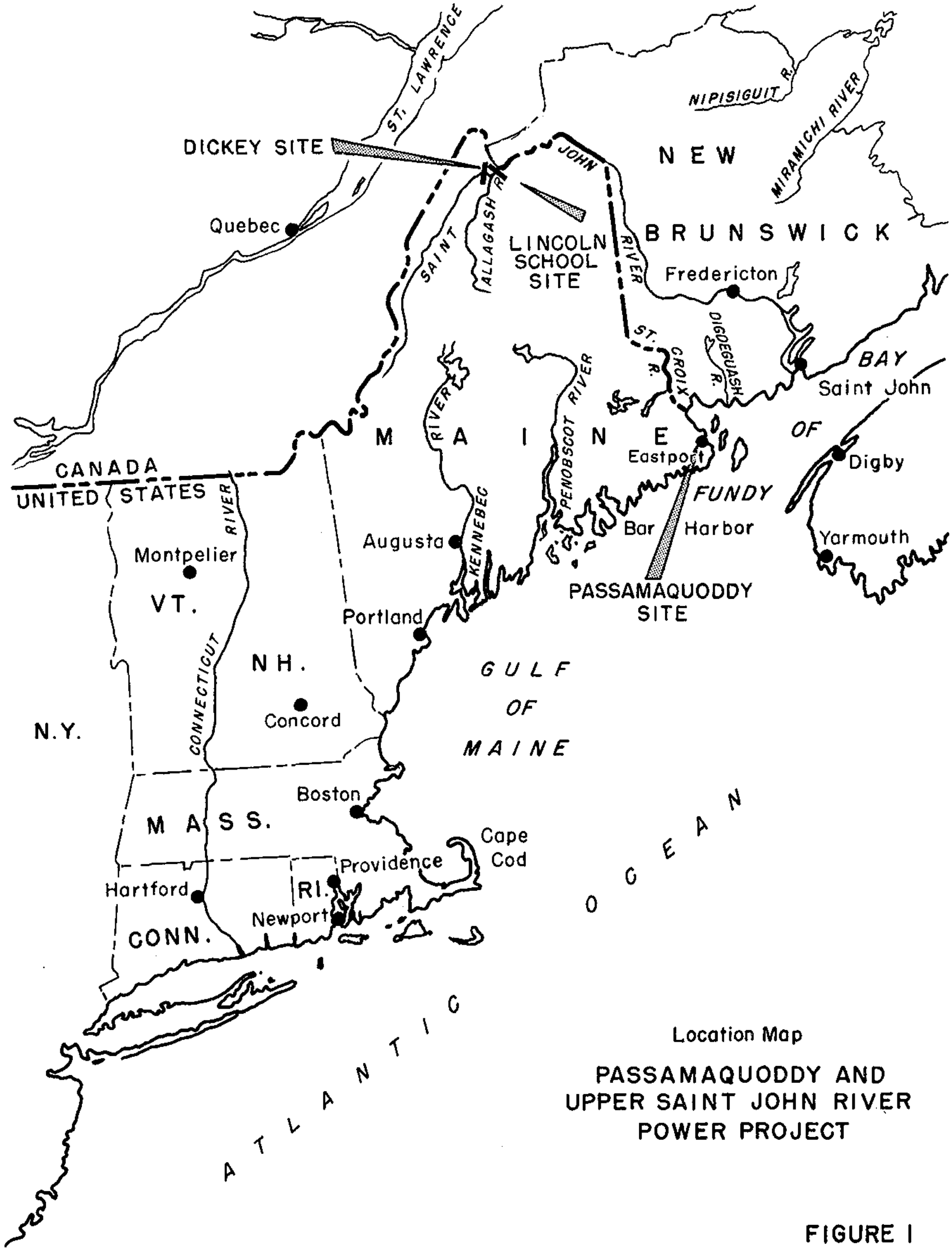
J. Karl Lee

J. Karl Lee

Joseph E. Guidry

Joseph E. Guidry, Project Engineer

Attachment



Location Map

PASSAMAQUODDY AND
UPPER SAINT JOHN RIVER
POWER PROJECT

FIGURE 1

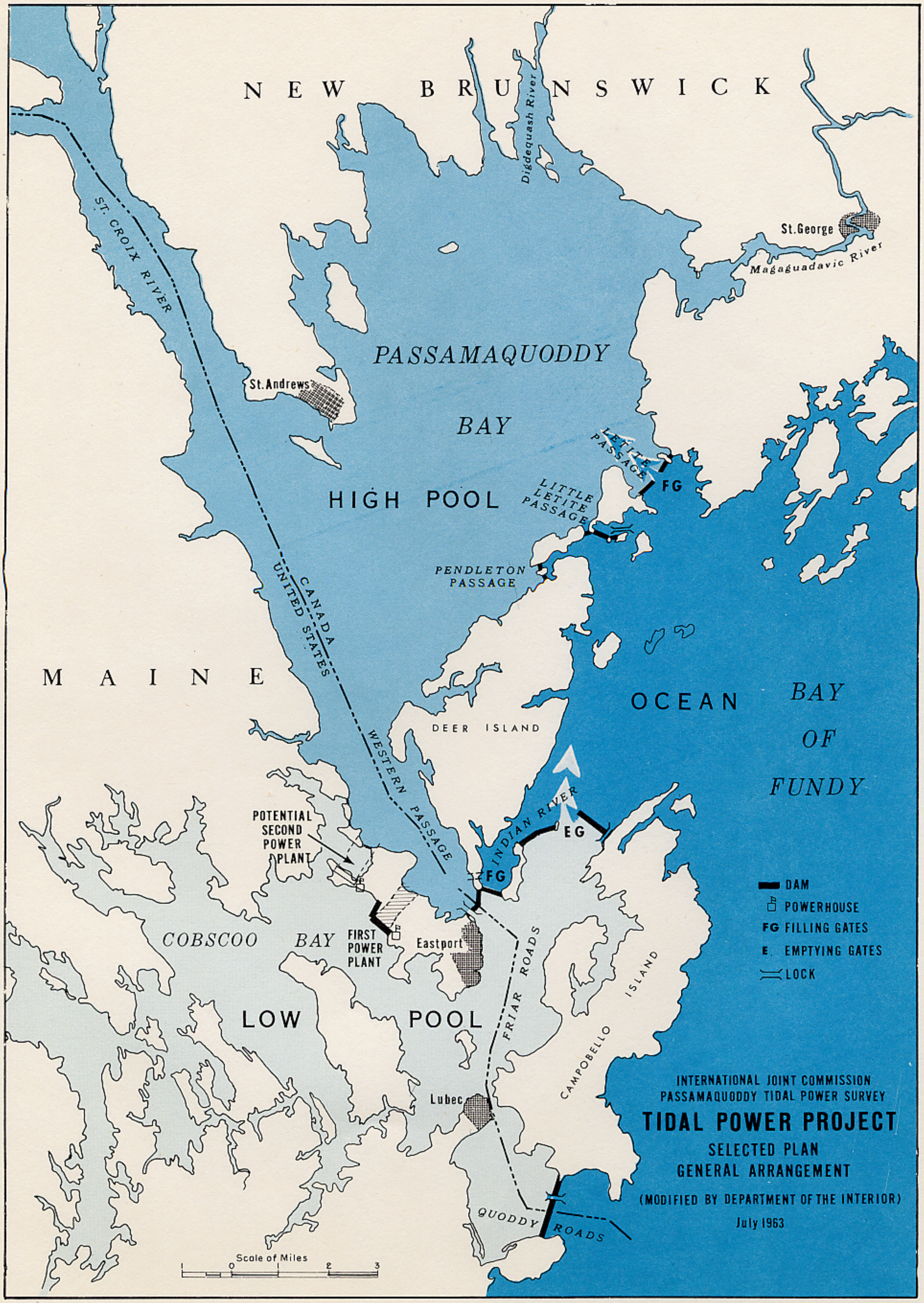

NEW BRUNSWICK
Digdequash River
St. George
Magaguadavic River
ST. CROIX RIVER
PASSAMAQUODDY
BAY
St. Andrews
LETITE PASSAGE
FG
HIGH POOL
LITTLE LETITE PASSAGE
PENDLETON PASSAGE
CANADA
UNITED STATES
MAINE
OCEAN
BAY OF FUNDY
DEER ISLAND
WESTERN PASSAGE
INDIAN RIVER
EG
FG
POTENTIAL SECOND POWER PLANT
FIRST POWER PLANT
COBSCOOK BAY
Eastport
FRIAR ROADS
CAMPOBELLO ISLAND
LOW POOL
Lubec
QUODDY ROADS
Scale of Miles
0
1
2
3
DAM
POWERHOUSE
FG FILLING GATES
E EMPTYING GATES
LOCK
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
TIDAL POWER PROJECT
SELECTED PLAN
GENERAL ARRANGEMENT
(MODIFIED BY DEPARTMENT OF THE INTERIOR)
July 1963

Figure 2

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Preface

For centuries man has observed the tides and envisioned their utilization as a source of useful energy. An eminent American engineer, Dexter P. Cooper, as far back as 1919, put forward a plan for harnessing the high tides in the Passamaquoddy area to develop electric power by building dams and sluiceways in the openings into the Bay of Fundy and a powerhouse between Passamaquoddy Bay and Cobscook Bay.

The International Passamaquoddy Engineering Board was appointed by joint agreement between Canada and the United States by authority of a reference on August 2, 1956 made in accordance with the Boundry Waters Treaty of 1909 and with United States Public Law 401, 84th Congress, 2d Session, approved January 31, 1956. This Board determined that a tidal power project could be built and operated in the Passamaquoddy area and that a two pool arrangement is best suited for the site conditions using the waters of Passamaquoddy and Cobscook Bays. On April 4, 1961 the International Joint Commission found that the Passamaquoddy Tidal Power Project was not economically feasible under present conditions. The IJC (International Joint Commission) recommended that development of the project be viewed as a long-range possibility having better prospects of realization when other less costly energy resources available to the area are exhausted. The Commission in this recommendation by the IJC pointed out that economic feasibility of the project may be affected by future changes in the costs and benefits considered in the evaluation of the project. Further, the IJC observed that the two Governments may wish to give consideration to the desirability of crediting the tidal project with certain public benefits that have not been included in the economic feasibility determinations presented in this report.

The IJC found that the combination of the Passamaquoddy Tidal Power Project and incremental capacity at Rankin Rapids on the Upper St. John River was most feasible. It further observed that changes in economic considerations, markets for power and technological changes and advances in construction and equipment could result in greater economic feasibility.

President Kennedy, by letter of May 20, 1961, requested the Secretary of the Interior, Stewart L. Udall, to review and evaluate the IJC's report. Upon completion of this review, the President requested the Secretary to advise of his judgment as to what changes in fuel, engineering and financing cost might result in making the project economically feasible. The President also requested advice on the advisability of hydroelectric power development on the Upper St. John River and other relative matters regarding the IJC report.

In December 1961, the Passamaquoddy - Upper St. John Study Committee had a Load and Resources Study made in the New Brunswick, Canada-New England areas. In this study, the knowledge, experience and expertise garnered in the Department of the Interior was utilized, and it clearly indicated that the Passamaquoddy Tidal

Power Project would be feasible if developed as a peaking powerplant in the magnitude of 1,000,000 kilowatts instead of 300,000 kilowatts as studied in the IJC report. This is consistent with current practices in the electric utility industry which are trending now to using large thermal electric generating units to meet the base load and hydro (conventional and pumped storage) for peaking. This development fits into the predicted future load requirements of the areas.

This preliminary investigation and study also made observations concerning the need for further study on low head axial flow turbines, operation of the tidal power project as a peaking plant, integration with other thermal and hydroelectric generation, and interconnection with electric utilities systems in Canada and the United States.

In the Public Works Bill for F. Y. 1963, Congress appropriated $200,000 for the Secretary to perform the basic studies required to determine the validity of the peaking power concept for the Passamaquoddy Tidal Power Project. These studies have been completed and are described herein. They clearly support the engineering and financial feasibility of the Passamaquoddy tidal power development for peaking purposes. The studies also clearly demonstrate the economic and financial feasibility of hydroelectric power development on the Upper St. John River.

Cooperating Agencies and Acknowledgements

The basic IJC report contained fundamental engineering studies and technical data prepared by the Corps of Engineers, the Federal Power Commission, and the New Brunswick Electric Power Commission. These agencies were contacted to a considerable extent throughout the course of the review and study and each agency was most cooperative in making all information available. The Corps of Engineers was particularly helpful in supplying all available information on the programing of the computer studies from the basic report, including basic designs and operating procedures and those contemplated for future operations. The Federal Power Commission furnished data on utility loads, generating facilities, and expected load growths and patterns for the future.

Complete cooperation was received within this Department. The Bureau of Reclamation made the horizontal axial flow turbine studies, the computer studies, the powerhouse and the transmission line designs, the review of the structural designs and construction cost, including the maintenance and replacement cost estimates. The Bureau of Outdoor Recreation, the Fish and Wildlife Service, and the National Park Service were most helpful.

Purpose and Scope of Report

The purpose of this report is to present the result of studies made to review the IJC's report on the International Passamaquoddy Tidal Power Project, April 1961. It includes the potentialities of hydroelectric power development on the Upper St. John River integrated and interconnected electrically with the Passamaquoddy Tidal Power Project and with the power systems of New England and New Brunswick.

The report examines further the findings of the preliminary Load and Resources Study which was released by the Department on March 6, 1962. This study was made for a power marketing area considerably more extensive than was used in the IJC's report but within economical transmission distance from the proposed Passamaquoddy Tidal Power Project and Upper St. John River hydroelectric powerplants.

The Load and Resources study emphasized the potential market for peaking power and developed the approach in which Passamaquoddy Tidal Power Project would be in the magnitude of 1,000,000 kilowatts instead of 300,000 kilowatts as proposed in the IJC's report. The Load and Resources Study predicated the development of a low cost horizontal flow hydraulic turbine and conducting extensive digital computer studies to demonstrate their performance and to obtain the capacity and energy output for the peaking operation at Passamaquoddy. Other studies on the cost of the deep water structures were suggested.

These studies have been completed and the results are given in terms of tangible power, recreation and area redevelopment benefits.

The major changes in the plan developed in this review compared to the plan of the Passamaquoddy Engineering Board in the IJC's report are:

(1) Increasing the Passamaquoddy Tidal Power Project installation from about 300,000 kilowatts to near 1,000,000 kilowatts.

(2) Operating the Passamaquoddy Tidal Power Project for short periods every day for peaking power production, which fits the anticipated load pattern of the area.

(3) Use of axial flow type hydraulic turbine in lieu of conventional vertical shaft turbine.

(4) On the Upper St. John River, constructing a major storage and power project at the Dickey site instead of Rankin Rapids.

(5) Some modification of the re-regulating dam and power production facilities at Lincoln School.

These modifications will not result in major problems. The axial flow hydraulic turbine was considered in the IJC's report, but at that time was not recommended because it appeared that the cost differential compared to a conventional type hydraulic turbine did not justify the use of the newer type hydraulic turbines. Additional technical, engineering, and cost information definitely support the use of axial flow hydraulic turbines.

Summary -- Findings

In response to the President's question in his letter of May 20, 1961, to Secretary Udall as to what changes in fuel, engineering and financing cost might result in making the Passamaquoddy Tidal Power Project economically feasible, the following has been determined:

(1) The Passamaquoddy Tidal Power project is feasible on current fuel prices which are essentially the same as those used in the IJC report.

(2) The Passamaquoddy Tidal Power project is feasible with the change in the engineering plan to provide peaking power in the order of 1,000,000 kilowatts capacity. The IJC report recommended developing the Passamaquoddy Tidal Power project for production of continuous base load power with about 300,000 kilowatts capacity.

(3) The project is feasible for development by the United States Government based on an interest rate of 2-7/8 percent as prescribed on July 26, 1962, by the Bureau of the Budget for project formulation. Power costs are repayable within 50 years after each power unit becomes revenue producing.

The Passamaquoddy Tidal Project powerplant would have an ultimate installed capacity of 1,000,000 kilowatts and the Dickey project would have an ultimate installed capacity of 750,000 kilowatts. The coordinated and integrated operation of these two plants would produce 1,000,000 kilowatts of dependable peaking capacity and 250,000 kilowatts of dependable capacity at 60 percent load factor delivered to the load centers. In addition, about one billion kilowatt hours of offpeak energy could be generated by Passamaquoddy and about 600 million kilowatt hours of energy at downstream hydroelectric plants of the New Brunswick Electric Power Commission. A reservoir and powerplant would be provided at the Lincoln School site for reregulation of releases from Dickey and generation power from the Allagash River flows. A transmission system would be available for the delivery of this power to load centers and its offpeak capacity could be utilized for delivery of power generated by others.

The proposal is feasible from an engineering and economic viewpoint. The benefit-cost ratio is 1.27 to 1.0 based on current project formulation principles and using an interest rate of 2-7/8 percent. Project repayment was envisioned at an interest rate of 2-7/8 percent.

Even though the Canadian Government has common interests in this proposal, the analysis has been based upon the standards and criteria applicable to such developments in the United States. The Canadian interests will be fully recognized and made the subject of negotiations with the Canadian Government as early as practicable.

Although core drillings and additional studies are needed to firm up the cost of the Dickey project, there is good evidence that the Dickey site is satisfactory to construct a storage and hydroelectric project as studied in this review report. The first 500,000 kilowatt powerplant of the Passamaquoddy Tidal Power project will utilize every facility which was envisioned in the IJC report for the development of the 300,000 kilowatt powerplant. The location of a second powerhouse at Passamaquoddy Tidal Power project for an additional 500,000 kilowatts is believed to be satisfactory. As usual, additional studies and design will be necessary for the orderly development of the Dickey project and the Passamaquoddy Tidal Power project.

The development of the Dickey site on the Upper St. John with a suitable reregulatory dam near Lincoln School affords an immediate opportunity for production of low cost load factor power for Maine and New England.

The early development of Passamaquoddy Tidal Power project coordinated with the Upper St. John River provides an opportunity for the development of a considerable additional load factor power at Dickey site and assures the generation of greater dependable peaking capacity at Passamaquoddy. Substantial benefits will accrue throughout the area by coordination and integration with existing power systems.

This development of an alternate source of low cost power creates an opportunity to enhance the fisheries of New England by removal of existing, small, inefficient hydro projects which now block the migration of anadromous fish. It also protects for all time the great recreational values of the Allagash River.

Power developed from these projects can be beneficially marketed in the New England-New Brunswick areas at cost of at least 25 percent lower than the average power cost in 1961, thereby strengthening the economy of the area and the Nation.

Recommendations

We recommend that:

(1) this report be sent to the Congress as a basis to seek early authorization of the International Passamaquoddy Tidal Power project, and the storage and hydroelectric development on the Upper St. John River, by the U. S. Army Corps of Engineers, and the marketing of the power by the Department of the Interior; and

(2) that the President instruct the Secretary of State to immediately initiate negotiations with the Government of Canada to work out a satisfactory arrangement for the sharing of the power benefits of the St. John River in Canada from storage on the Upper St. John River in the United States, and the development of the Passamaquoddy Tidal Power project by the United States.

The Tide--An Energy Resource

In contemplating the potential of Passamaquoddy, it is essential to recognize that the tide is a perpetual energy resource, fully predictable and dependable.

The level of the sea alternately rises and falls, even in the most sheltered locations and in the calmest weather, completely independent of surface disturbances from wind and waves. This rhythmic motion of the tides has been observed by man for centuries.

The alternate rise and fall of the sea is due to forces which are astronomic in origin and dependent on the relative positions of the earth, sun and moon. The height of the tide varies with these forces and the physical configuration of the coast line. When the attractive forces of the sun and moon are in conjunction, or opposition, as at a new moon and full moon, their combined action produces a tide greater than usual,called the spring tide. When the moon is at first or third quarter, the tide is unusually low and is called the neap tide. There are generally two complete tidal cycles, that is, two high tides and two low waters each day. This is the case in the Passamaquoddy Bay area.

The greatest rise and fall of the tides in the world occurs in the head of the Bay of Fundy on the Nova Scotia Coast where tides as high as 40 to 50 feet are observed.

At Eastport, Maine, also on the Bay of Fundy, similar tides are experienced, but of lesser magnitude. The maximum observed tidal range at this location is 26 feet with a minimum of 12.7 feet and an average tidal range of 18.1 feet. These are the tides which make possible the development of the Passamaquoddy Tidal Power Project.

International Joint Commission Plan

The report of the International Passamaquoddy Engineering Board sets forth the results of a comprehensive survey to determine the engineering and economic feasibility of developing the international tidal power potential of Passamaquoddy Bay in Maine and New Brunswick. It includes investigations of the engineering and economic aspects of the tidal project by itself; the engineering and economic aspects of the tidal project combined with an auxiliary source of power supply to supplement the varying output of the tidal powerplant; the market for and value of the power from the tidal power project with and without an auxiliary; and the possible effects that construction of the tidal project may have on the regional and national economies.

The Board conducted a series of field investigations and studies of site conditions in the Passamaquoddy-Cobscook Bay area. These investigations included aerial mapping, deep and shallow water drilling, land drilling, underwater mapping, analysis of soils, and tidal gauging. Core drilling in great water depths and high tidal velocities and underwater mapping with sonic equipment constituted two of the most costly and difficult undertakings of the survey.

The project arrangement selected for design included the 101 square miles of Passamaquoddy Bay as the high pool and the 41 square miles of Cobscook Bay as the low pool, with a powerhouse located at Carryingplace Cove.

The selected IJC plan would have provided an installed generating capacity of 300,000 kilowatts, a dependable capacity of 95,000 kilowatts, and an average annual generation of about 1,843 million kilowatt-hours.

This plan called for 90 filling gates, 40 in Letite Passage and 50 between Western Passage and Indian River. In the reach between Pope and Green Islets 70 emptying gates, similar to the filling gates set at a lower elevation, would empty the lower pool. Four navigation locks were planned for this tidal project. The outdoor type powerhouse would have 30 generating units of 10,000 kilowatts rated capacity, each with an overload of 15 percent. The turbines selected were fixed-blade propeller type.

A comparison of the performance of fixed-blade and Kaplan turbines indicated that the greater efficiency of the Kaplan turbine was offset by its greater cost. The horizontal-axis, bulb-type turbine-generator recently developed in Europe and adopted for use in the single-pool tidal project in LaRance Estuary on the northwest coast of France was also studied by the Engineering Board for possible use in the Passamaquoddy project. This unit can be used as a turbine, pump, or sluiceway, with flow in either direction.

Studies by the Board showed that the bulb-type turbine-generator develops approximately as much power as the Kaplan, and structural studies indicated that the powerhouse structure would cost about $300,000 less per unit than with conventional units. This saving, however, was offset by the greater cost of the bulb-type turbine-generator set and the need to compensate for electrical stability due to low rotative inertia. The Board adopted the conventional fixed-blade type in its plan for the Passamaquoddy project.

In order to supplement the varying output from the tidal power project, the Board considered several different auxiliary power sources to determine the best type for meeting the power loads of the region. These studies included river hydroelectric plants, pumped-storage plants, and steam-electric auxiliaries.

A number of river hydroelectric sites were examined and Rankin Rapids on the Upper St. John River in Maine was selected by the Board as the best source of auxiliary power. The Rankin Rapids project would provide 2.8 million acre-feet of usable storage capacity. Operated in conjunction with the Passamaquoddy tidal plant, the combined project would provide 555,000 kilowatts of dependable capacity and 3.063 million kilowatt-hours of average annual generation.

Four project combinations were selected by the Board for evaluation of costs and benefits. These were: (1) the Passamaquoddy tidal project alone; (2) the tidal project operated in combination with all the Rankin Rapids project; (3) the tidal project supplemented by incremental capacity only at Rankin Rapids; and (4) the tidal project supplemented by the Digdequash pumped-storage auxiliary.

Four conclusions of the International Passamaquoddy Engineering Board which are particularly pertinent to the Department of the Interior's review are quoted as follows:

"(1) A tidal power project using the waters of Passamaquoddy and Cobscook Bays can be built and operated. The two-pool type of project is best suited for the site conditions in the area and the power markets it would serve. The tidal project arrangement selected makes best use of the site conditions.

"(2) The first cost (construction cost) of the tidal power project by itself would be $484 million. With interest during construction, the investment would be $532.1 million. The tidal power project would have an installed capacity of 300,000 kilowatts and a dependable capacity of 95,000 kilowatts. Average annual energy would be 1,843 million kilowatt-hours. However, for maximum power benefits, the tidal power project would have to be combined with an auxiliary power source.

"(3) The most favorable project combination is the tidal power project operated in conjunction with a river hydroelectric auxiliary built at the Rankin Rapids site on the upper St. John River in Maine. The combined cost of the tidal project and the Rankin Rapids auxiliary is $630 million. With interest during construction, the investment would be $687.7 million. The dependable capacity of this combination would be 555,000 kilowatts, and average annual generation would be 3,063 million kilowatt-hours.

"(4) Construction of the tidal project - Rankin Rapids combination would increase low flows in the lower St. John River by a considerable amount, thus increasing substantially the usefulness of the river for downstream generation of power. Downstream benefits accruing to existing powerplants were included in the economic evaluation."

Department of the Interior Plan

The basic plan envisioned by the Department of the Interior proposes Passamaquoddy developed as a peaking powerplant supplying a substantial portion of all the peaking power requirements of an extensive marketing area embracing the New England States and the New Brunswick area. This need stems from the anticipated load pattern forecast for the area which would have a substantial peak and the ever-increasing use of large capacity, more or less fixed output, thermal generating plants to supply the base load. Tidal power which is essentially hydroelectric power with the added features of dependability and predictability is particularly suitable for supplying peaking power. The plan envisions use of the basic two pool concept developed in the IJC's report with the significant modification that horizontal flow turbines would be utilized in the powerplant instead of the conventional vertical shaft turbine generator units. In subsequent sections of this report, the computer studies, which demonstrated the feasibility of the peaking power operation, are discussed, as well as development of the horizontal axial flow turbines, the study of deep water structures and the general impact of peaking power operation in the tidal development.

Other Tidal Developments

The only tidal development for electric power under full-scale construction today is the LaRance Tidal Project in France. This site was visited by Assistant Secretary Holum and his Assistant and Chief Engineering Research Advisor Morgan Dubrow on their return from a four-day symposium on Peak Load Coverage in Venice, Italy, May 20-23, 1963. A portion of their report is quoted as follows:

> "This project is presently the largest tidal project under construction in the world. It will have an initial power installation of 240 megawatts in 24 turbine sets and could have an ultimate installation of 320 megawatts. It is being built at an approximate cost of about $80 million and represents the continued effort of French engineers over a 20-year period to harness the energy of the tides at San Malo. The site is ideal for the construction of such a tidal project because it is a narrow estuary with a tidal range of 13-1/2 meters (that is roughly 44 feet). The LaRance Tidal Project is operated for peaking capacity or energy. Since the units are reversible, it is designed to take whatever advantage of the tides for generation to fit into the power loads of the French electric system.
>
> The LaRance Tidal Project which is under construction certainly inspires the officials and engineers of the Department of the Interior who have been concered with the review of the Passamaquoddy Tidal Power Project and the St. John River. Every effort will be made to quickly obtain authorization and make plans for construction of the Passamaquoddy Project coordinated with the St. John River."

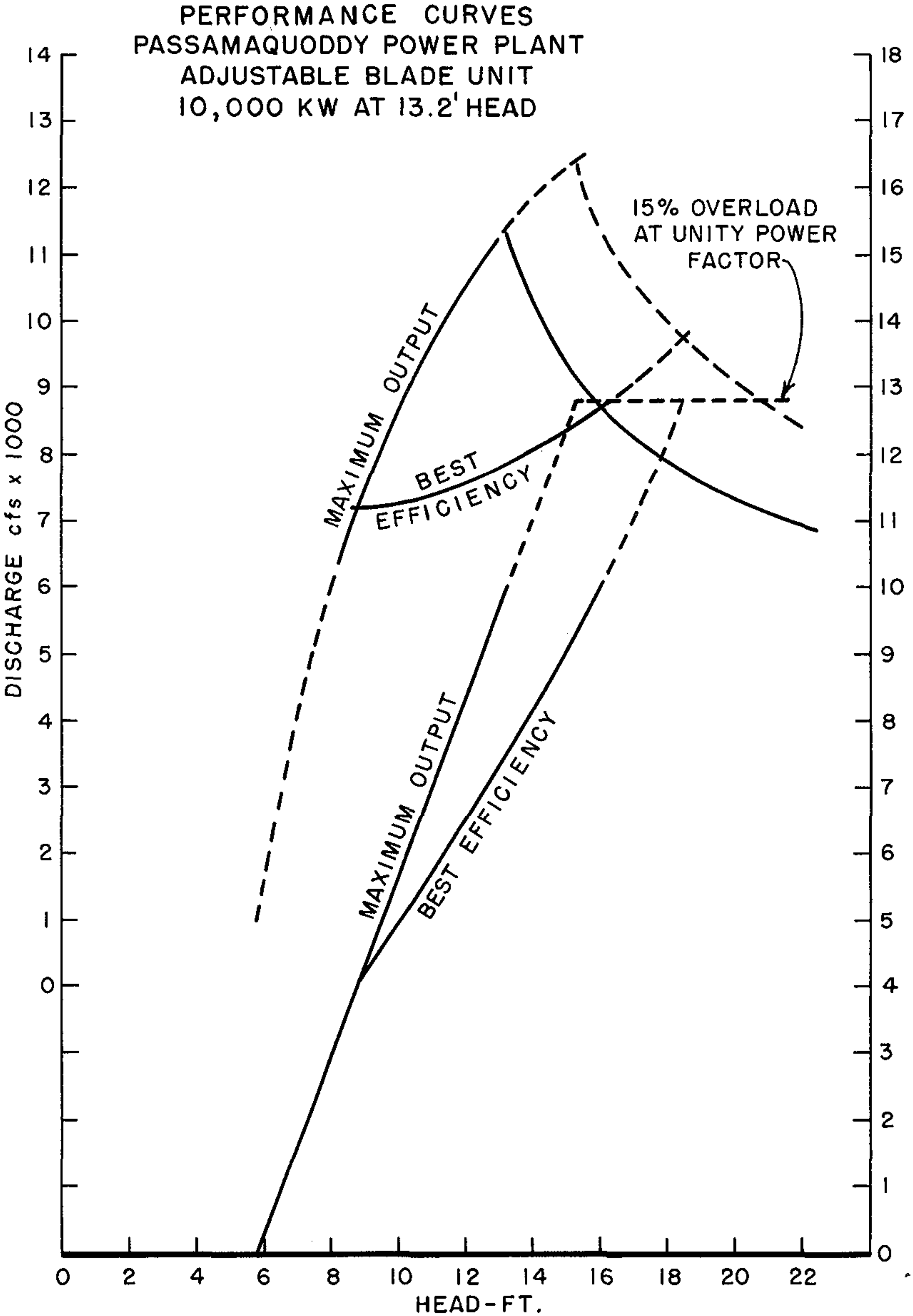
Horizontal Axial Flow Turbines

One of the first steps in the current study was to contact all known turbine manufacturers to determine the availability of horizontal axial flow turbines to obtain their operating characteristics and cost. Personal visits were made with engineering personnel of the Allis-Chalmers Manufacturing Company, York, Pennsylvania; Neyrpic, New York, New York; Westinghouse Electric Manufacturing Company, Philadelphia, Pennsylvania; and the English Electric Company. Correspondence was conducted and replies received from the James Leffel & Company, Springfield, Ohio; Baldwin-Lima-Hamilton Corporation, Philadelphia, Pennsylvania; Newport News Shipbuilding and Dry Dock Company, Newport News, Virginia; Dominion Engineering Company, Ltd., Montreal, Quebec, Canada; Nichimen Company, Incorporated, New York, New York; Mitachi New York Ltd., New York, New York; and Vevey Engineering Works, Ltd., New York, New York.

The basic designs advanced by the Allis-Chalmers Company utilizing an "inclined-shaft" and the Neyrpic Company's French "bulb-type" were the only two types currently available, as was found by the International Joint Engineering Board.

The Office of the Chief Engineer, Bureau of Reclamation, concentrated on improving and developing a suitable type of horizontal flow turbine, illustrated in the report. This turbine would be of the adjustable blade propeller type with the shaft inclined at about 30 degrees from the horizontal, the waterways as straight as possible, and with the conventional air cooled type generator located above the water line. Each unit would be rated at 14,000 horsepower, 10,000 kw at 13.2 feet of head, 43.4 rpm. There would be fixed stay vanes but no wicket gates. The propeller blades would close when a unit is shut down. All parts exposed to sea water would be either stainless steel or stainless steel clad to protect against corrosion. The shaft would be hollow to provide maximum rigidity with least weight. Guide bearings would be water lubricated. The two-way thrust bearing would be between the turbine and generator and would be oil lubricated. Expected performance of this unit is shown in Figure 3.

During the course of the investigations, the French bulb-type horizontal flow turbine generator was inspected by the Assistant Secretary for Water and Power and by the Chairman of the Passamaquoddy Study Committee. These units are being further investigated by the Office of the Chief Engineer of the Bureau of Reclamation. We have shown a turbine based on a proposal of the Allis-Chalmers Manufacturing Company because it offers complete electrical reliability, simplicity of design, and low construction cost. Undoubtedly other turbine manufacturers also will be able to produce a satisfactory low-head turbine adaptable to this use.



PERFORMANCE CURVES
PASSAMAQUODDY POWER PLANT
ADJUSTABLE BLADE UNIT
10,000 KW AT 13.2' HEAD
15% OVERLOAD
AT UNITY POWER
FACTOR
MAXIMUM OUTPUT
BEST
EFFICIENCY
MAXIMUM OUTPUT
BEST EFFICIENCY
DISCHARGE cfs x 1000
KW x 1000
HEAD-FT.
0
2
4
6
8
10
12
14
16
18
20
22

FIGURE 3

Tidal Powerplant

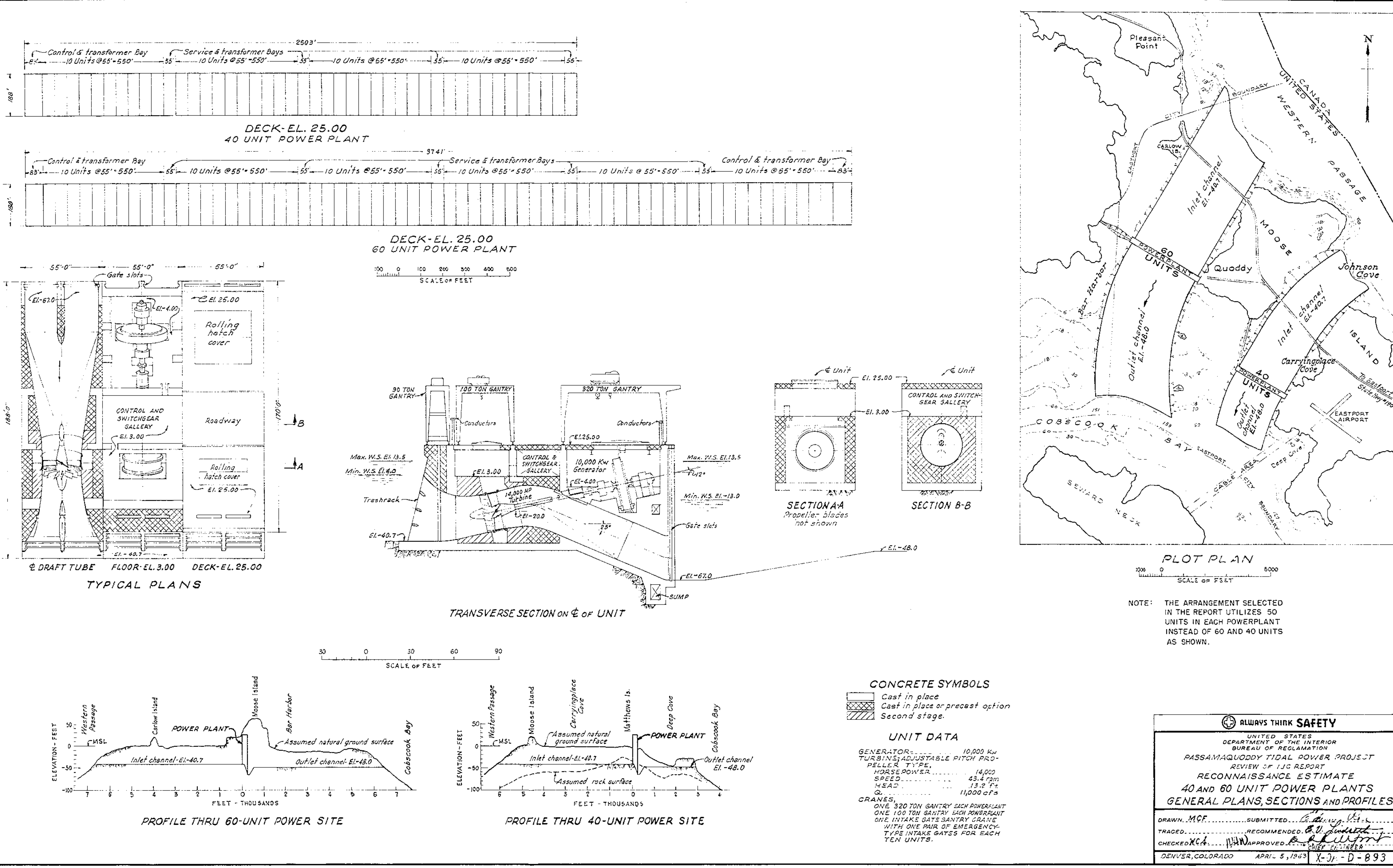
The IJC report recommended that the powerplant be installed with a capacity of 300,000 kilowatts. In the Department's proposed plan a capacity in the magnitude of one million kilowatts is proposed. This would require a powerplant about twice the length of a 300,000-kilowatt structure so that sites other than Carryingplace Cove were necessarily considered. Four additional plant locations were studied, using basic data from the IJC report. The best location for a second powerplant site was in the vicinity of Bar Harbor.

The best plan is to provide the million kilowatts of capacity in two 50-unit powerplants of 500 megawatts each, one at Carryingplace Cove and the second at Carlow Island. It was believed that the geologic formations at Bar Harbor were about the same as Carryingplace Cove. The rock and common excavations for the channels and plant were estimated from the Carryingplace Cove proportions and a contingency added for unknowns.

The powerplant has been considered as a semi-outdoor reinforced concrete structure. Access to the equipment is provided through rolling hatches located over each unit. A 320-ton gantry crane would travel over the hatchways for installation and servicing the generator units and a 100-ton gantry crane would install and service the turbines. A 90-ton gantry with spare emergency-type intake gates will also be provided for each 10 units. Service decks, operating galleries and space for control, cable and piping runs would be provided within the structure. Emergency gates at the upstream end and bulkhead gates at the downstream end of the waterway will permit unwatering for inspection and maintenance.

Floating caissons, precasting, and cast-in-place construction methods were reviewed. A combination of precast concrete members and cast-in-place construction seems to offer the best in speed and least in unit bay cost. Accordingly, the structure is arranged to permit 40 percent of the concrete volume to be precast at the contractor's option.

The intake and discharge channels at Carryingplace Cove are arranged in a manner similar to this channel in the IJC report. The channel at Bar Harbor would be approximately 4,000 feet longer which adds considerably to the cost per kilowatt of a unit bay at this site. Of the two plant locations as shown on the plot plan on Figure 4, the most restricted water passage will be in the inlet channel between Johnson and Carryingplace Coves. Here the inlet channel will be excavated and pinched down in width to confine it to the neck of land extending between the Passamaquoddy and Redoubt Hill areas. The velocity of the water passing through this restricted passage will most likely be greater than anywhere else in the inlet and outlet channels of both plants.



DECK-EL. 25.00
40 UNIT POWER PLANT
DECK-EL. 25.00
60 UNIT POWER PLANT
Control & transformer Bay
Service & transformer Bays
10 Units @ 55' = 550'
SCALE OF FEET
Gate slots
Rolling hatch cover
CONTROL AND SWITCHGEAR GALLERY
Roadway
℄ DRAFT TUBE
FLOOR-EL. 3.00
DECK-EL. 25.00
TYPICAL PLANS
90 TON GANTRY
100 TON GANTRY
320 TON GANTRY
Conductors
Max. W.S. El. 13.5
Min. W.S. El. 4.0
Trashrack
10,000 Kw Generator
14,000 HP Turbine
Gate slots
SUMP
TRANSVERSE SECTION ON ℄ OF UNIT
SECTION A-A
Propeller blades not shown
SECTION B-B
PLOT PLAN
Pleasant Point
CANADA
UNITED STATES
WESTERN PASSAGE
MOOSE ISLAND
Quoddy
Johnson Cove
Carryingplace Cove
Bar Harbor
Inlet channel El. -40.7
Outlet channel El. -48.0
60 UNITS POWERPLANT
40 UNITS POWERPLANT
COBSCOOK BAY
SEWARD NECK
EASTPORT AIRPORT
NOTE: THE ARRANGEMENT SELECTED IN THE REPORT UTILIZES 50 UNITS IN EACH POWERPLANT INSTEAD OF 60 AND 40 UNITS AS SHOWN.
PROFILE THRU 60-UNIT POWER SITE
PROFILE THRU 40-UNIT POWER SITE
ELEVATION - FEET
FEET - THOUSANDS
Assumed natural ground surface
Assumed rock surface
Inlet channel - El. -40.7
Outlet channel - El. -48.0
CONCRETE SYMBOLS
Cast in place
Cast in place or precast option
Second stage.
UNIT DATA
GENERATOR ... 10,000 Kw
TURBINE; ADJUSTABLE PITCH PROPELLER TYPE,
HORSEPOWER ... 14,000
SPEED ... 43.4 rpm
HEAD ... 13.2 ft
Q ... 11,000 cfs
CRANES,
ONE 320 TON GANTRY EACH POWERPLANT
ONE 100 TON GANTRY EACH POWERPLANT
ONE INTAKE GATE GANTRY CRANE WITH ONE PAIR OF EMERGENCY-TYPE INTAKE GATES FOR EACH TEN UNITS.
ALWAYS THINK SAFETY
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PASSAMAQUODDY TIDAL POWER PROJECT
REVIEW OF IJC REPORT
RECONNAISSANCE ESTIMATE
40 AND 60 UNIT POWER PLANTS
GENERAL PLANS, SECTIONS AND PROFILES
DRAWN MCF
SUBMITTED
TRACED
RECOMMENDED
CHECKED
APPROVED
CHIEF ENGINEER
DENVER, COLORADO
APRIL 5, 1963
X-D-893

FIGURE

For the maximum flow of 440,000 cfs, the velocity in the restricted passage will be the least, 4.7 feet per second, when the upper and lower pool elevations are 13.50 and 0.3, respectively, and the greatest, 5.7 feet per second, when the upper and lower pool elevations are 4.0 and 9.2, respectively.

Deep Water Structures and Gates

The IJC's report indicates that a large portion of the project cost is involved in the deep water structures in Western Passage, Indian River, and Head Harbour Passage. In view of its experience in deep water construction cost, the Bureau of Yards and Docks of the Navy was requested to review the IJC's report and to advise whether there were any breakthroughs in construction techniques or design which occurred since the preparation of the IJC's report which might hold promise for reducing the cost of the deep water structures and coffer dams required during the construction phases. The Bureau of Yards and Docks concluded from their review that due to the thoroughness and modernity of the investigations, no major construction breakthroughs can be offered. However, several suggestions for reducing costs were offered, as shown in the quoted portion of the report, on the next page.

The Chief Engineer's office of the Bureau of Reclamation concurred that there might be an opportunity for saving money in the actual construction phases, but that it may be necessary to add some additional embankment material.

In order to determine the impact of peaking power operation on the gates, a review was likewise made of the IJC recommendations. This review indicated general concurrence with the IJC design, but additional studies for prevention of icing with consideration of an alternate type of gate design using a horizontal shaft, square leaf, butterfly valve are desirable.

The following is quoted from the report of the Bureau of Yards and Docks which was transmitted to the Department of the Interior on January 22, 1963:

"Review of the project studies indicates that a high degree of thoroughness has been applied to the investigations. Because of this thoroughness and modernity, no new major construction breakthroughs can be offered. However, some observations and suggestions are submitted for consideration.

a. The Board's investigation so far has logically not been done with the intention of producing definitive designs for the various installations of dams and coffer dams, but with the idea of producing simple schematic outlines to be used as bases for computing cost conservative estimates. These estimates are then applied in relation to the benefits to be derived in determining the relative cost benefit ratios for the project. There is no doubt that, in succeeding stages of preliminary and finalized design, refinements would be made which would result in some savings for certain features of the work and thus would tend to reduce the preliminary estimates. However, due to the complex nature of the project, it is equally probable that conditions unforeseen in the preliminary investigation analyses will result in added costs probably offsetting possible savings. Without going through the complete steps of detailed design, it would be highly inadvisable to introduce additional cost saving concepts as a basis for justifying reduced estimates and thus risk the hazards that these could not be realized in the overall project cost.

b. The evaluation studies performed by the International Passamaquoddy Engineering Board have been carried sufficiently far to include consideration of:

(1) Various types of core material and several arrangements and combinations of materials in the cross sections of the structures.

(2) Armoring methods based on generally standarized procedures.

(3) Coffer dam structures employing standard tried and true examples in both shallow and deep water. The schemes are based on sound and conservative engineering principles and are probably the only safe bases for evaluating a project of this type.

(4) Depositing of the fills based primarily on the use of standard barges which are of about 1400 ton maximum capacity. These are probably the cheapest methods so far devised for placing rock in large quantity.

c. If the project generates sufficient interest to justify employment of further study effort in the next planning stage, the following list contains items which are typical of those which might be investigated:

(1) Greater accuracy of control for the deposit of the materials for the cores of the dams. The three methods of placement described in the Board Report are bottom dump scows, end-dumping trucks working out from shore, and special bottom dump buckets which would be lowered through the water by crane. The utilization of hinged trunks or tremies on the bottom dump barges may be more effective in preventing scatter and lateral transport by swift currents. It would be well also to consider the possibility of using flat decked barges equipped with articulated tremies into which bulldozers on the decks could push the materials. Another alternative would be the employment of vertical towers with elevator operated skips for placement of materials. The use of underwater television cameras for determination of surface contours of the partially completed mounds would be a refinement in overall control methods. Imprisonment of the sand before dumping by packaging it in plastic bags and dumping the bags, instead of the raw materials, would result in greater accuracy and less segregation than by surface dropping, but the relative economy of this method would have to be proven.

(2) Alternative methods of transport for the core materials like cable ways and belt conveyors. The quantities involved are so tremendous that there must be an enormous transport system. A fleet of only two or three barges would probably match any cableway. This project would probably use 20 or 30 barges.

(3) Further refinement in the widths and design slopes of the mound, with an eye toward reduction in the total quantities required. These refinements would have to keep in mind the various design criteria to satisfy environmental conditions of wave action, currents, percolation rates, and foundation conditions. For example, if wave action were the only criteria, the side slopes of the dams could probably be made steeper, with ample stability, based on experience with a recently constructed breakwater at the Naval Station, Newport, R. I.

(4) Use of nuclear energy explosions for building the dams. There is a possibility that in the future methods may be developed so that by the use of nuclear explosives it would be possible to reduce the cost of some features of this project. This is not within present engineering talent capability.

(5) Placement of the smaller size core materials by means of a hydraulic dredge with submerged pipeline and discharge.

d. The order of magnitude of any possible economies may not prove to be large enough to be really significant in changing the present over-all picture. It should be remembered that a significant reduction in the total cost of the dam and coffer dam structures, below that reflected in the present cost estimates will be difficult of accomplishment unless unusual breakthroughs can be applied to all phases of the design and construction features. It would be really unusual for such a set of conditions to prevail. A breakthrough on some one important feature may significantly reduce its cost but the impact of this reduction on the total cost of structures would be felt to much lesser extent.

e. In the implementation of a construction project of this magnitude, the advisability of using a system of Program Evaluation and Report Techniques similar to the PERT system should be considered. Weather conditions prevailing at this site would certainly dictate the use of carefully planned methods for the scheduling of construction. A system like PERT with machine control and guidance would be an almost indispensable aid to successful accomplishment of the entire construction program.

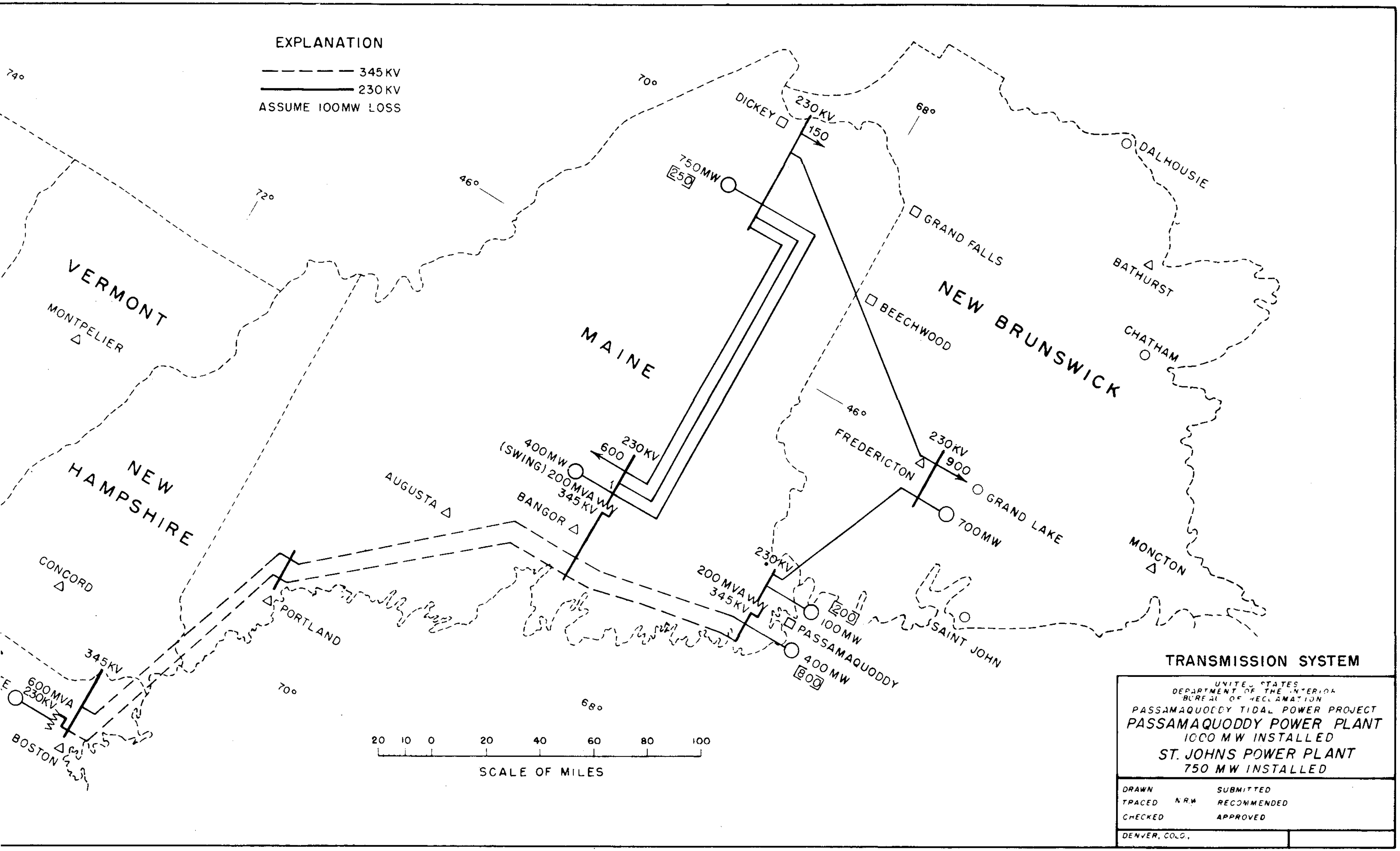
f. It would not be basically sound to predict a large reduction in the presently estimated total cost of the dam and coffer dam structures. The possible methods of reducing costs outlined above are all subject to confirmation as to feasibility and relative economy. No doubt savings can be made and opportunities will be found in the later design stages for certain features. However, it is very doubtful that these savings will offset costs now unforeseen which will inevitably arise during a detailed design. The estimates are probably properly conservative for an evaluation of a project of this degree of complexity. It is believed that the cost estimates have properly been based on concepts which are reasonable, feasible, sound, and conservative, but which are subject to refinement in later, more detailed studies."

Transmission System

The project plan envisions a basic transmission system interconnecting the Passamaquoddy Tidal Powerplant with the Dickey Plant on the Upper St. John River serving Maine, other areas in New England, and New Brunswick, and terminating in the Boston, Massachusetts, area. A diagram of the ultimate transmission plan developed by the Chief Engineer, Bureau of Reclamation, is included in Figure 5 of the report.

Two 345 Kv transmission circuits are visualized for delivery of power to Boston with a switching point at Bangor, Maine, for interconnecting with three 230 Kv transmission circuits from the Dickey powerplant to Bangor, Maine. These lines are primarily designed for the project purposes, but their offpeak capacity could be utilized by other power systems in the area. The power transmission system was designed for stable operation following double line to ground faults near the powerplants.

The Transmission Diagram indicates lines extending to Fredericton, New Brunswick, which could deliver power to Canada providing suitable arrangements are made.



EXPLANATION
345 KV
230 KV
ASSUME 100MW LOSS
VERMONT
MONTPELIER
NEW HAMPSHIRE
CONCORD
MAINE
AUGUSTA
BANGOR
PORTLAND
BOSTON
NEW BRUNSWICK
DICKEY
GRAND FALLS
BEECHWOOD
DALHOUSIE
BATHURST
CHATHAM
FREDERICTON
GRAND LAKE
MONCTON
SAINT JOHN
PASSAMAQUODDY
750MW
250
400MW
(SWING) 200MVA
345KV
230KV
600
150
900
700MW
200 MVA
200
100MW
400 MW
800
600MVA
230KV
SCALE OF MILES
TRANSMISSION SYSTEM
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PASSAMAQUODDY TIDAL POWER PROJECT
PASSAMAQUODDY POWER PLANT
1000 MW INSTALLED
ST. JOHNS POWER PLANT
750 MW INSTALLED
DRAWN
TRACED N.R.W.
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
DENVER, COLO.

FIGURE 5

Cost Estimates

This study is basically a review of the IJC's plan for the Passamaquoddy Tidal Power Project; hence, the cost estimates used in the IJC's report were utilized to the maximum extent. In those instances where variations exist, cost estimates were prepared by the Chief Engineer's Office of the Bureau of Reclamation, Denver, Colorado. The cost estimates used in the report are as follows:

Passamaquoddy Construction Costs

Same as 1959 Report

Item	Installed Capacity 500-MW	Installed Capacity 1,000-MW
Power Plant	$157,771,400	$351,375,200
Filling Gates	64,585,300 ✓	64,585,300
Emptying Gates	61,108,300 ✓	61,108,300
Locks	20,187,500 ✓	20,187,500
Dams	80,261,000 ✓	80,261,000
Lubec Channel	633,500 ✓	633,500
Fishways	919,100 ✓	919,100
Relocations	3,914,000 ✓	4,500,000
Lands and damages	1,859,000 ✓	2,500,000
Subtotal	$391,239,100	$586,069,900
Contingencies	68,369,400	110,924,500
Subtotal	$459,608,500	696,994,400
Engr. design, Supr. & adm.	41,364,800	62,295,000
Total	$500,973,300	$759,289,400

Passamaquoddy Operation, Maintenance and Replacement Cost

Item	Installed Capacity 500-MW	Installed Capacity 1,000-MW
Operation & Maintenance		
Powerplant	$1,385,000	$2,750,000
Switchyard	89,000	225,000
Subtotal	$1,474,000	$2,975,000
Gates & Locks	250,000	250,000
Total	$1,724,000	$3,225,000
Replacements		
Power Facilities	366,000	742,000
Total	366,000	742,000
Total OM&R	$2,090,000	$3,967,000

Dickey Powerplant Construction Cost

Item	Installed Capacity 150-MW	Installed Capacity 450-MW	Installed Capacity 750-MW
Lands & Damages	$5,116,000	$5,116,000	$5,116,000
Relocations	150,000	150,000	150,000
Dams	67,250,000	67,250,000	67,250,000
Powerplant	22,520,000	59,640,000	95,880,000
Switchyard	1,100,000	2,000,000	3,600,000
Buildings, grounds& facilities	840,000	840,000	840,000
Access road & railroad	1,252,000	1,252,000	1,252,000
Subtotal	98,228,000	136,248,000	174,088,000
Engr. design, Supr. & adm.	8,841,000	12,262,000	15,668,000
Total	107,069,000	148,510,000	189,756,000

Dickey Operation, Maintenance and Replacement Cost

Item	Installed Capacity 150-MW	Installed Capacity 450-MW	Installed Capacity 750-MW
Operation & Maintenance			
Powerplant	$282,000	$742,000	$1,200,000
Switchyard	32,000	58,000	104,000
Subtotal	$314,000	$800,000	$1,304,000
Dam & Reservoir	20,000	20,000	20,000
Total	$334,000	$820,000	$1,324,000
Replacements			
Power Facilities	63,700	164,400	264,500
Total	63,700	164,400	264,500
Total OM&R	$397,700	$984,400	$1,588,500

Transmission Cost

A broad estimate of the anticipated transmission requirements for the project area is approximately as follows:

	Stage I	Stage II	Stage III
Construction cost	$18,000,000	$50,000,000	$92,000,000
Annual operation, maintenance and replacement cost	150,000	439,000	538,000

Economic and Financial Analysis--Project Evaluation

The economic justification and financial feasibility of the potential Passamaquoddy-Upper St. John project were analyzed using the current evaluation procedures adopted by the U. S. Government. Project benefits and costs were calculated for a 100-year period of analysis using a 2-7/8 percent interest rate. Recreation and area redevelopment were included as project purposes. On the basis of these analyses, it was found that the potential Passamaquoddy-Dickey power development is economically justified. Project benefits would exceed project costs in the ratio of 1.27 to 1.

Although we propose that the Tidal Power Project and Upper St. John River Development be fully integrated, our economic analysis clearly indicates that either project is financially feasible and could stand on its own feet as a separate project.

The project was also found to be financially feasible. Repayment of the cost allocated to power could be accomplished with interest at 2-7/8 percent on the unpaid balance within a period of 50 years after each power unit becomes revenue producing. The cost allocated to recreation and area redevelopment would be nonreimbursable.

The project is assumed to be developed on the following schedule:

Stage I--Construction of Dickey Dam and Reservoir and initial installation of 150 megawatts of power generating facilities.

Stage II--Construction of Passamaquoddy Tidal Basin facilities and installation of 500 megawatts of power generating facilities at Passamaquoddy and an additional 300 megawatts of power generating facilities at Dickey powerplant.

Stage III--Completion of the 1,000-megawatt installation at Passamaquoddy and 750-megawatt ultimate installation at Dickey.

It was assumed that construction of Stage II facilities would be completed five years after completion of Stage I facilities, and the construction of Stage III facilities would be completed ten years after the completion of Stage II facilities.

Benefits and Costs

Construction of the Passamaquoddy-Dickey power development would create annual equivalent benefits with associated annual equivalent Federal project costs and benefit-cost ratios as follows:

	Benefits	Costs	Benefit-Cost Ratio
Stage I	9,845,000	3,856,000	2.55 to 1.0
Stage II	29,235,000	24,427,000	1.20 to 1.0
Stage III	46,849,000	36,872,000	1.27 to 1.0

Benefits

Benefits creditable to the project were analyzed for three project purposes--power, recreation, and area redevelopment. A discussion of the benefits for each of these purposes follows.

Power Benefits--The annual equivalent power benefits from the potential Passamaquoddy power development are estimated to be $42,129,000. The standard energy-capacity approach was followed in estimating these power benefits. The energy and capacity values used in this analysis were based on the alternative costs of obtaining equivalent power supplies in the New England-New Brunswick area, utilizing the cost of highly efficient, large size privately financed thermal plants in the Boston area. Allowance was made for transmission costs in converting these power values to at-site conditions. The unit power values used in evaluating power benefits are summarized below; and the estimates of dependable capacity, average annual energy generation, and power benefits for the potential project for initial and full development are summarized in the attached table.

Item		Value
Average Annual Energy	Maine	4.1 mills per kw-hr
Average Annual Energy	Boston	3.2 mills per kw-hr
Average Annual Energy	Downstream	3.2 mills per kw-hr
Capacity		Per kw.
Dickey		
At-Market Value		--
Less Transmission		--
At-Site Value		$31.20
Passamaquoddy Peaking		
At-Market Value		$29.15
Less Transmission		3.00
At-Site Value		$26.15

Power Benefits and Related Data
Potential Passamaquoddy-Dickey Power Development

	Initial Stage of Development	Full Development
Capacity	Mw.	Mw.
Dickey	150	750
Passamaquoddy	--	1,000
Dependable Capacity - Dickey	150	250
" " - Passamaquoddy	--	1,000
Adjusted for 10% Losses - Dickey	136	225
" " " - Passamaquoddy	--	9
Annual Energy	Mwh.	Mwh.
Total Energy		
At-Site Production - Dickey	751,000	1,250,000
" " - Passamaquoddy	--	1,318,000
Downstream Production	656,000	656,000
Adjusted for 8% Losses		
At-Site Production - Dickey	695,000	1,150,000
" " - Passamaquoddy	--	1,213,000
Downstream Production	607,000	607,000
Annual Power Benefits	Total ($1,000)	Total ($1,000)
Capacity - Dickey	4,243	7,020
" - Passamaquoddy	--	23,535
Energy - Dickey - At-Site	3,475	5,750
" - Dickey - Downstream	1,942	1,942
" - Passamaquoddy	--	3,882
Total	9,660	42,129

Recreation Benefits

The recreational aspects of the potential Passamaquoddy Tidal development have been studied by the Bureau of Outdoor Recreation. Passamaquoddy Bay and Cobscook Bay, where the Passamaquoddy Tidal Power Project would be located, offer a panorama of water and scenic views which are complemented by the Fundy Isles of Campobello, Deer Island, and Grand Manan, all located in Canada.

The principal attraction to tourists in the area would be the tidal power project itself. An engineering marvel, its operations would feature the rise and fall of the tides, the impounding of water in two natural pools, navigation locks for unrestricted movement of boats, emptying and filling gates, and power transmission.

While the population trend of the Nation and the State of Maine has been generally going up, the number of persons living in Washington County, headquarters of the proposed project, decreased considerably from 1950 to 1960. Of all the counties in the State, Washington County has the lowest median income. Construction of the tidal power project would greatly increase its recreation potential and economic status.

Many thousands of persons who now visit other parks and attractions in the area doubtless would combine their trips to those areas with a stopover at Passamaquoddy. Acadia National Park is only 130 miles south of the proposed tidal power project, and West Quoddy Head State Park and Moosehorn National Wildlife Refuge are located nearby.

Because of the uniqueness of the proposed Passamaquoddy Tidal Power Project and its potential attraction for travellers, it is recommended that outdoor recreation provisions be made in project development plans for:

1. A visitor center with adequate parking facilities.
2. Interpretative signs at appropriate points and working models of the tidal power project to be housed in the visitor center.
3. Picnic areas.
4. Boat launching sites at convenient locations.
5. Frequent roadside overlooks.

Construction of these facilities not only would enhance visitors' enjoyment of the Passamaquoddy project, but would complement attractions of Maine's Quoddy Head Park and the Federal Government's Moosehorn National Wildlife Refuge.

The Bureau of Outdoor Recreation estimates the annual recreation visitation to Passamaquoddy at present is about 216,000 visitor-days and would be 500,000 visitor-days under 1975 conditions.

The number of visitors is expected to increase to 4,675,000 in the year 2025. The desirability of outdoor recreation is enhanced by such attractions as Acadia National Park, other state recreation areas and associated recreation activities in the Passamaquoddy Project, shown on Figure 6.

The average annual benefits associated with this recreation activity adjusted for the changes over time are estimated to be $2,065,000 based on recreational values of $0.80 per visitor-day. It is recognized that there are recreation benefits on the Upper St. John River, but these have not been evaluated for inclusion in this study.

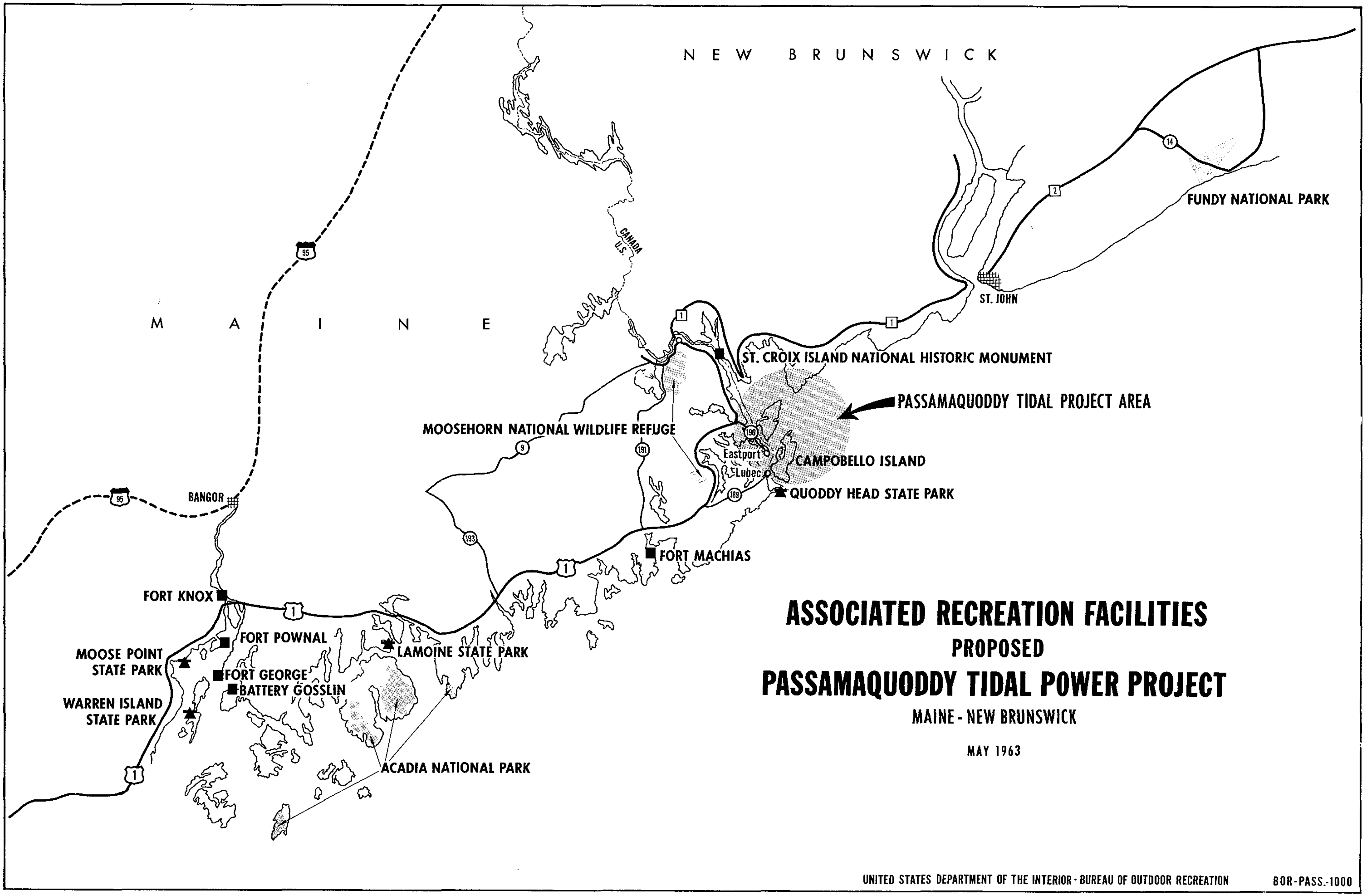

NEW BRUNSWICK
MAINE
FUNDY NATIONAL PARK
ST. JOHN
CANADA
U.S.
ST. CROIX ISLAND NATIONAL HISTORIC MONUMENT
PASSAMAQUODDY TIDAL PROJECT AREA
MOOSEHORN NATIONAL WILDLIFE REFUGE
Eastport
Lubec
CAMPOBELLO ISLAND
QUODDY HEAD STATE PARK
BANGOR
FORT MACHIAS
FORT KNOX
FORT POWNAL
MOOSE POINT STATE PARK
LAMOINE STATE PARK
FORT GEORGE
BATTERY GOSSLIN
WARREN ISLAND STATE PARK
ACADIA NATIONAL PARK
95
1
2
9
14
189
190
191
193
ASSOCIATED RECREATION FACILITIES
PROPOSED
PASSAMAQUODDY TIDAL POWER PROJECT
MAINE - NEW BRUNSWICK
MAY 1963
UNITED STATES DEPARTMENT OF THE INTERIOR · BUREAU OF OUTDOOR RECREATION
BOR-PASS.-1000

FIGURE 6

Area Redevelopment Benefits

Both the Passamaquoddy and Dickey power developments are located within counties which are designated as "redevelopment areas" based on criteria set forth in the Area Redevelopment Act of 1961 (75 Stat. 47); therefore, construction of the potential project would significantly reduce unemployment in these two areas.

Current evaluation procedures require the measurement of benefits attributable to the value of labor required for the construction and operation of a project that otherwise would not be fully utilized. Such benefits are identified in this analysis as area redevelopment benefits.

In evaluating the benefits which would accrue from area redevelopment, wages paid to skilled and unskilled labor required for project construction and salaries paid to personnel for project operation were considered. Labor inputs necessary for the construction of the potential project were estimated through use of information obtained from water resource projects recently constructed by the Bureau of Reclamation. Information on the present extent of unemployment in the affected labor-market areas and the character of the unemployed labor force was obtained from the Employment Security Commission, State of Maine. Utilizing this information, the available local unemployed labor force was compared with the projected construction work requirements by construction years to estimate the amount of increased employment of the local labor force creditable to project construction. The associated construction wages converted to annual equivalent values for a 100-year period of analysis were used as the construction employment component of the area redevelopment benefits.

Salaries and wages paid to the permanent operating personnel were estimated and used in evaluating the contribution of project operation to local employment. However, in accordance with current procedures of the Department of the Commerce, the overall employment period was established at 20 years from initiation of construction on the first phase of the project, and a declining scale of values reaching zero in the 21st year was utilized. The employment benefits associated with project operation were evaluated as the annual equivalent of this series of declining values when spread over the 100-year period of analysis for the project. The annual area redevelopment benefits creditable to the Passamaquoddy-Dickey power development as estimated in the manner described are $2,655,000.

Additional information relating to the area redevelopment analysis is presented in the following table:

Area Redevelopment Benefits

Passamaquoddy-Dickey Power Development

Item	Initial Stage of Development	Full Development
Local Labor Utilized, Construction		
Man Years	1,160	14,116*
Total Wages	$4,800,000	$80,360,000
Operation and Maintenance		
Annual Wages and Salaries	$ 200,000	$ 2,729,000
Annual Equivalent Benefits		
Construction	$ 147,000	$ 2,453,000
Operation and Maintenance	38,000	202,000
Total Benefits	$ 185,000	$ 2,655,000

* Based on three-stage construction

Flood Control

Since the storage on the Upper St. John will afford almost complete regulation of the river above the Dickey Dam in Maine substantial flood control protection will be provided for the Lower St. John River. In this connection the following paragraph is quoted from the IJC report:

> "Flood Control. Damages from floods occur with some regularity along the Saint John River, and the damages would be reduced by an upstream storage project. The extent of these annual damages, as indicated in the first three items in the attached correspondence is a substantial loss to the area, but very small compared to the power benefits of the projects being considered. Flood control benefits which might accrue would have only a small effect on the benefit-cost ratio of the tidal project and its auxiliary, therefore, further study in this direction was not undertaken."

The actual e~tent of flood protection afforded will need to be studied in detail and evaluated in order that they may be considered in future negotiations with the Canadian government.

Fish and Wildlife

The basic IJC report contains a report from the Fisheries Board. The following information from the Bureau of Fish and Wildlife of the Department indicates that there are no adverse effects on fish and wildlife from the Passamaquoddy Tidal Power project:

> In response to your request of March 6, 1961, to the Bureau of Sport Fisheries and Wildlife, the Service has reviewed the report on the Passamaquoddy Tidal Power project. Personnel of the Bureau of Sport Fisheries and Wildlife in Boston and the Bureau of Commercial Fisheries in Gloucester have discussed the matter with the Passamaquoddy-St. John Study Committee. Based on this review and the discussions, the Fish and Wildlife Service concludes that further studies of the marine fisheries or sport fisheries and wildlife as they would be affected by construction and operation of the Passamaquoddy project would not be required at this time. The Service reaffirms its opposition to any use of the Rankin Rapids Dam and Reservoir as a source of supplemental power because the construction of this project would flood the Allagash River.

The Passamaquoddy Committee believes that with the availability of Passamaquoddy power in Eastern Maine and load factor power from the Upper St. John River, the possibility is increased for restoring the once abundant Atlantic salmon to some of the small coastal streams in that part of the state. Most of these streams now contain small inefficient hydroelectric powerplants and upstream storage developments which block the migration of anadromous fish. These obstacles to fish migration could be eliminated with the development of the alternate sources of power envisioned in this report.

Summary of Benefits

The benefits presented above are summarized in the following tabulation:

Summary of Estimated Annual Benefits

Item	Amount	
	Initial Stage	Ultimate Stage
Power	9,660,000	42,129,000
Recreation	--	2,065,000
Area Redevelopment	185,000	2,655,000
Total	9,845,000	46,849,000

Benefit-Cost Ratio

The ratio of benefits to costs for the first stage of development is 2.55 to 1, and for the full development, 1.27 to 1.

Cost Allocation

The costs of the potential project have been allocated among the three functions of power, recreation, and area redevelopment using the alternative justifiable method of allocation, a 100-year period of analysis, and 2-7/8 percent interest. The basic allocation in the following table, is summarized below.

Project Purpose	Construction	Int. during Construction	OM&R
Power	$847,119,000	$68,279,000	$5,482,000
Area Redevelopment	57,322,000	4,584,000	41,000
Recreation	44,605,000	3,537,000	32,000
Total Project	$949,046,000	$76,400,000	$5,555,000

Federal Project Costs

Annual Federal costs associated with the benefits for the potential Passamaquoddy-Dickey power development are estimated at $36,872,000 based on a 100-year analysis and 2-7/8 percent interest. The comparable estimate for the initial level of development is $3,856,000. The derivation of these estimates is shown below.

Initial Phase of Development	In Total
Construction Costs	107,069,000
Interest during Construction	6,156,000
Total Investment	113,225,000
Annual Equivalent Investment Cost	3,458,000
Annual Operating Costs	398,000
Total Annual Equivalent Costs	3,856,000
Full Development	
Construction Costs	949,046,000
Interest during Construction	76,400,000
Total Investment	1,025,446,000
Annual Equivalent Investment Cost	31,317,000
Annual Operating Costs	5,555,000
Total Annual Equivalent Costs	36,872,000

Cost Allocation

Passamaquoddy-Dickey Power Development

Item	Power	Area Redevelopment	Recreation	Total Project
	$1,000	$1,000	$1,000	$1,000
Costs to be allocated				
Construction				949,046
Interest during const.				76,400
O&M				4,549
Replacements				1,006
Annual Equivalent Values				
Benefits	42,129	2,655	2,065	46,849
Alternative costs	36,872	*	*	--
Justifiable expenditure	36,872	2,655	2,065	41,592
Specific costs				
Construction	17,540	--	--	17,540
Interest during const.	1,420	--	--	1,420
O&M	4,279	--	--	4,279
Replacements	1,006	--	--	1,006
Total	24,245	--	--	24,245
Remaining justifiable exp.	12,627	2,655	2,065	17,347
Percentage	(72.79)	(15.31)	(11.90)	(100.00)
Joint costs				
Construction	8,330	1,752	1,362	11,444
Interest during const.	665	140	108	913
O&M	197	41	32	270
Replacements	--	--	--	None
Total	9,192	1,933	1,502	12,627
Total Allocated costs				
Construction	25,870	1,752	1,362	28,984
Interest during const.	2,085	140	108	2,333
O&M	4,476	41	32	4,549
Replacements	1,006	--	--	1,006
Total	33,437	1,933	1,502	36,872
Summary of Allocated Costs				
Construction	847,119	57,322	44,605	949,046
Interest during const.	68,279	4,584	3,537	76,400
O&M	4,476	41	32	4,549
Replacements	1,006	--	--	1,006

* Exceeds benefits

Project Repayment

A financial repayment analysis was made using an interest rate of 2-7/8 percent on the unpaid balance and a repayment period of 50 years after each power unit becomes revenue producing. The results of this study show that repayment could be accomplished by the following power rates:

Dependable Peaking Capacity	-- $24 per kilowatt year
Energy	-- 4.0 mills per kilowatt hour

Passamaquoddy Hydrologic Studies

The objective of the hydrologic studies was to determine the feasibility of operating the Passamaquoddy Tidal Power Project as a peak load plant. The studies were based on the assumption that the project proposed by the International Passamaquoddy Engineering Board presented the most desirable plan except for installed capacity and method of powerplant operation.

The extensive studies performed by the Engineering Board were generally directed toward obtaining the greatest amount of energy from the tides. The selected project plan proposed the use of two tidal pools, a high pool and a low pool. The method of operation entailed filling the high pool during high tides and emptying the low pool during low tides, the energy being generated by continuously passing water from the high to the low pool through a 300,000 kw powerplant. The generation of the greatest amount of energy severely limits the peaking capability of the project since at times minimum generation is produced during maximum energy demand. This results from the fact that the 24-hour and 50-minute tidal cycle is out of phase with the 24-hour solar day which governs energy demand.

The two pool plan is easily adaptable to a peaking method of operation. The primary consideration is that the two pools be operated to provide the maximum amount of head on the powerplant turbines at the start of each peaking period. During the high tide prior to a peaking period, the high pool is filled to the highest possible elevation. Similarly, during the low tide prior to a peaking period, the low pool is emptied to the lowest possible elevation. These pool elevations are then maintained until the start of the peaking period. Following the peaking period, offpeak or secondary energy can then be produced until the time and tides are such that the pools must be filled or emptied in preparation for the next peaking period.

To determine the feasibility of a peaking method of operation, the project was analyzed using installed capacities ranging from 500 mw to 1,000 mw. The data used in the studies except for turbine performance curves were taken from the Report to the IJC by the Engineering Board. The turbine performance curves were developed by the Office of Chief Engineer of the Bureau of Reclamation.

Computer Studies

The basic operating plan for Passamaquoddy as a "peaking" power plant involves the following basic steps:

a. Filling the Upper Pool through the filling gates to the maximum height possible from the tide.

b. Holding the water in the Upper Pool until power is desired; then releasing the water through the power plant to the Lower Pool.

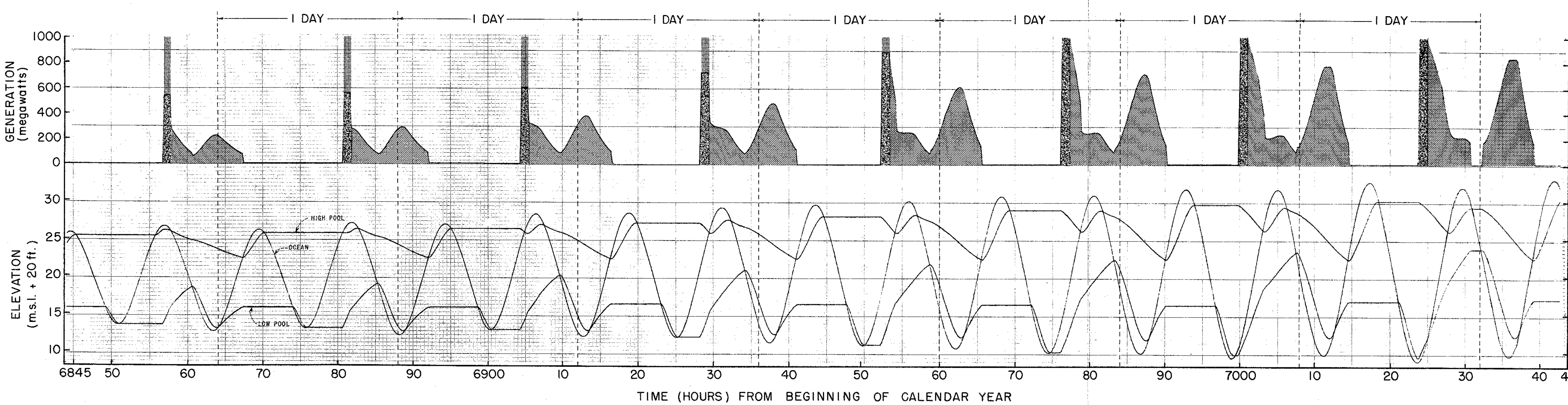
c. Releasing the water in the Lower Pool to the ocean through the emptying gates whenever the tide is below the level in this pool.

This plan differs from the IJC plan only in the fact that water would be released as required to meet "peaks" rather than continuously to supply the base load.

The electricity utility load pattern for the New England-New Brunswick area to be served by Passamaquoddy-St. John has had only one sharp peak each day. Since there is at least one high tide each day, the Passamaquoddy plant can always meet this daily peak. Other alternate tides can be utilized for generation of offpeak power. Since the tides are predictable and dependable, the tide required to meet an anticipated peak load can be detected well in advance of its occurrence.

In view of the repetitious nature of the tides and the vast amount of labor which would be required for computations, an electronic computer was used for routine studies and power calculations. A sample print-out from the computer is shown on Figure 7.

There follows a series of output curves of the Passamaquoddy operation with installations of 50 to 100 units peaking power durations varying from 30 minutes to one hour and 30 minutes. These charts are shown on Figure 8.



FIRMING CAPACITY FROM DICKEY

PASSAMAQUODDY PEAK GENERATION

OFF PEAK GENERATION

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PASSAMAQUODDY TIDAL POWER PROJECT

POOL OPERATION AND POWER GENERATION
DURING NEAP AND SPRING TIDES

1000 MEGAWATT POWER PLANT CAPACITY
1.0 HOUR PEAKING PERIOD

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

REVISED WASHINGTON 6/21/63
MAY 14, 1963

FIGURE 7

PASSAMAQUODDY FOR PEAKING

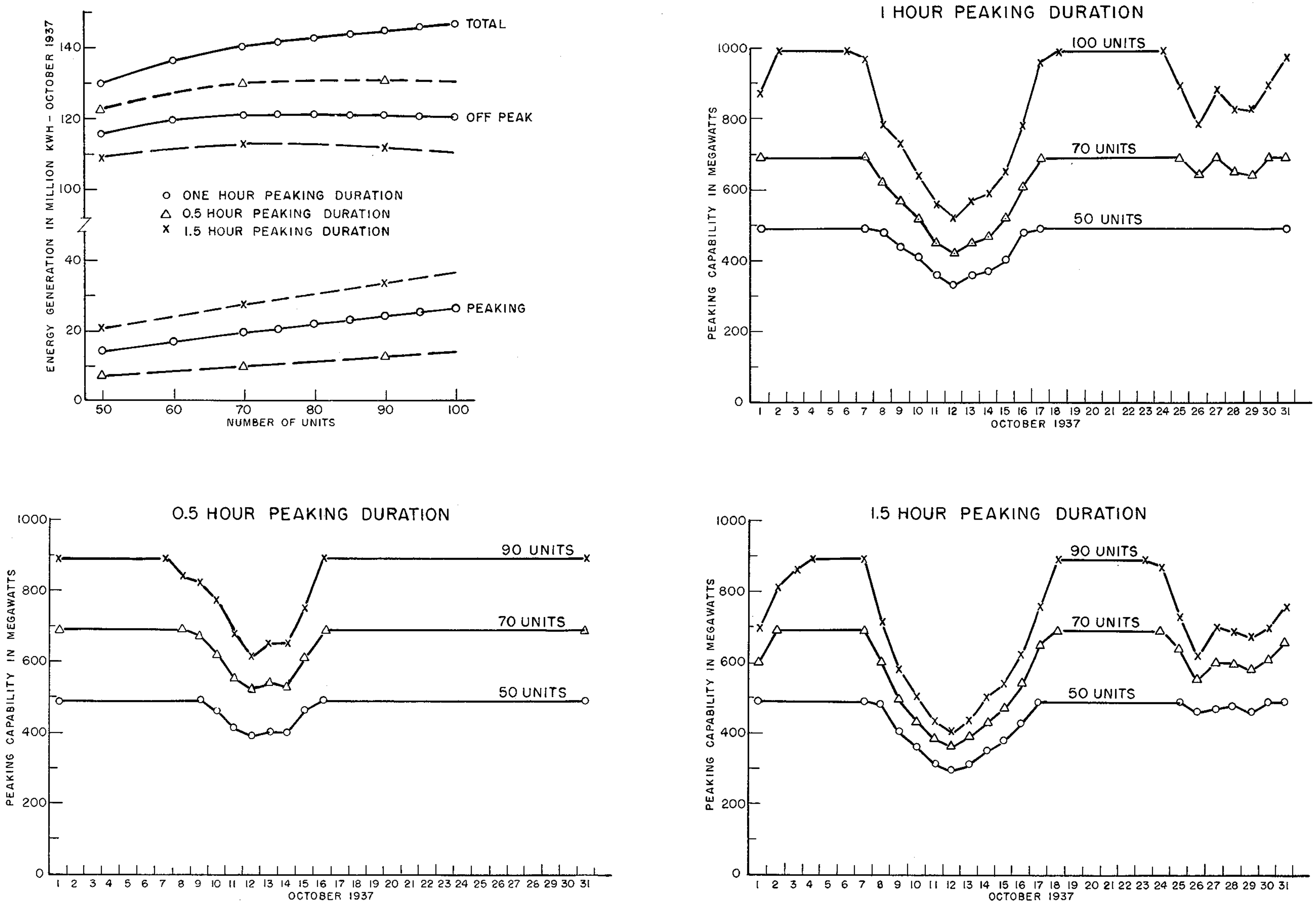


FIGURE 8

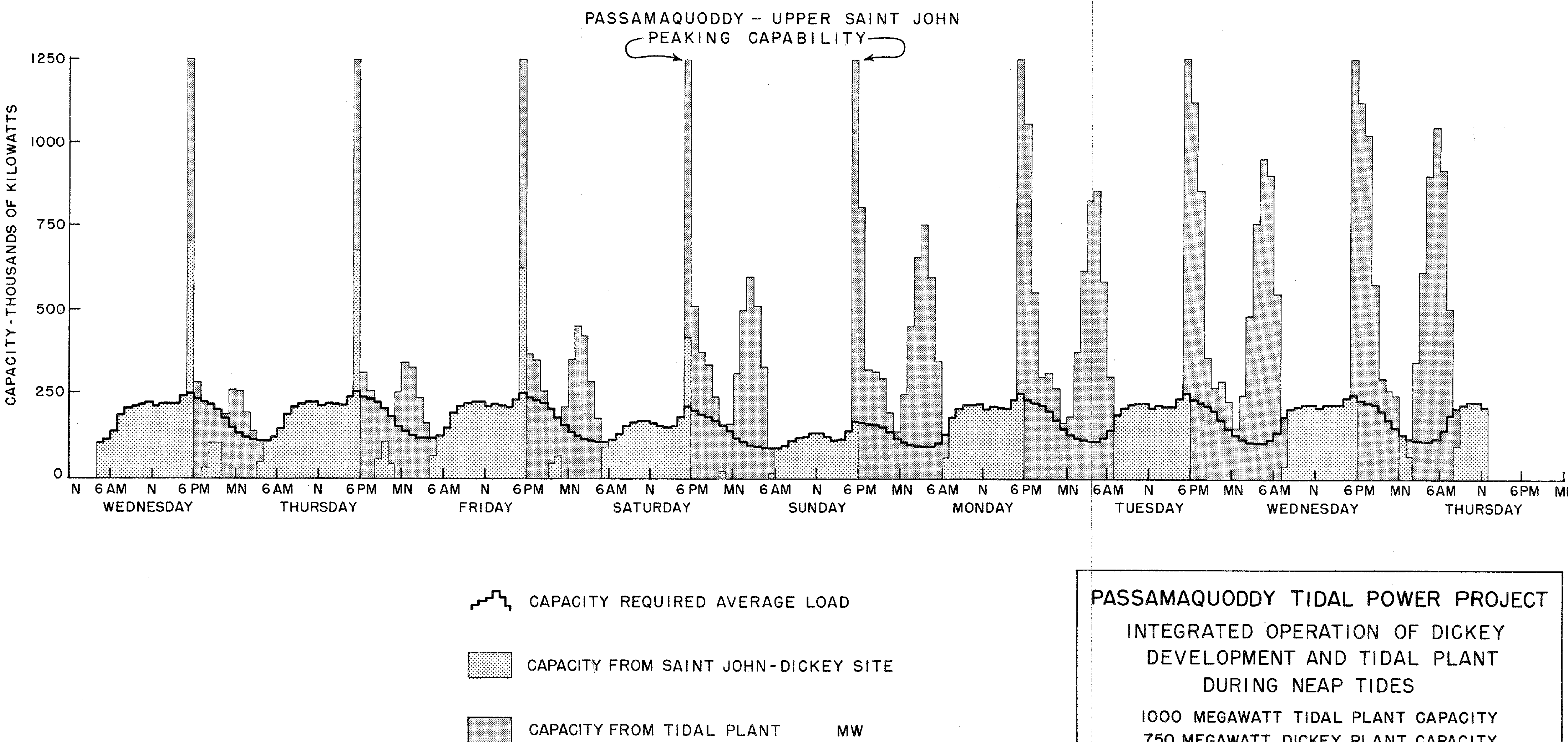
St. John River-Hydrologic Studies

The objective of hydrologic studies of the St. John River was to evaluate the feasibility of a coordinated operation of the tidal powerplant with potential developments on the river. Such a coordinated operation would be desirable to integrate a large part of the tidal off-peak energy with the St. John energy making it possible that it could then be utilized as firm energy. Further, additional installed capacity could be provided in the river plant to meet the peaking requirement for the increased firm energy and to firm up the tidal peaking capability during neap tides.

Pertinent streamflow records available for studying the St. John River are as follows:

Station	Available record	Drainage area
St. John River below Fish River at Fort Kent Maine	Oct 1926-1960	5,690 sq mi
Fish River near Fort Kent, Maine	Sept 1929-1960	871 sq mi
Allagash River near Allagash, Maine	Sept 1931-1960	1,250 sq mi
St. John River at Dickey, Maine	Sept 1946-1960	2,700 sq mi

For hydrologic studies, streamflow records for the Allagash river and St. John River at Dickey were extended back to September 1929 by correlation with other stations. The four records were then used to derive monthly runoff values for damsites at Big Rapids, Dickey, Rankin Rapids, and Lincoln School. Mass curves of runoff versus time, constructed for the main storage sites, indicate that the critical low runoff period of record on the St. John River extended from July 1955 through March 1958. Figure 9 illustrates the coordinated operation of the Passamaquoddy Tidal Power project with the Dickey powerplant. This is based on an installed capacity of 1,000,000 kilowatts in Passamaquoddy and 750,000 kilowatts in Dickey which would provide a dependable capacity of 1,250,000 kilowatts, of which 250,000 from Dickey is usable as load factor power and 1,000,000 kilowatts as dependable peaking capacity.



PASSAMAQUODDY TIDAL POWER PROJECT
INTEGRATED OPERATION OF DICKEY DEVELOPMENT AND TIDAL PLANT DURING NEAP TIDES
1000 MEGAWATT TIDAL PLANT CAPACITY
750 MEGAWATT DICKEY PLANT CAPACITY

FIGURE 9

A representative of the Passamaquoddy-St. John River Study Committee personally inspected the Dickey site. No bedrock was visible on the surface as is true of the Rankin Rapids and Big Rapids sites. Large boulders, however, are visible as at the other two sites. Since the Dickey site is located between the Big Rapids and the Rankin Rapids sites, both of which are known to have good geologic conditions as determined from core drilling, it was reasonably concluded that the Dickey site was also satisfactory geologically. The valley at this dam site is about 1/2 mile wide with a faster rise on the left bank (north side) than on the right bank.

The left bank reaches a height of about 1500 feet approximately 1 mile from the river, while the right bank top elevation at 1 mile is about 1200 feet. The river surface at the site is about 600 feet and the proposed reservoir would be at elevation 910 feet.

A general inspection of the area indicated that construction of a dam at Dickey would be less costly than one at Rankin Rapids. Utilization of the Dickey site would necessitate a reregulating reservoir as in the case of the Big Rapids site. However, because of encroachments on the tailwater at Dickey, the Lincoln School reregulating power would have to be modified.

The following table gives comparative values for the various plans considered.

Comparative Values of Power Sites
Upper St. John River
Integrated With Passamaquoddy Power Plant

	Rankin Rapids	Dickey-Mod. Lincoln School	Big Rapids Lincoln School
Installed Capacity	410 mw	360 mw	390 mw
BENEFITS			
At Site			
Firm Capacity MW	340	280	250
Energy (Million Kwhrs)	1,700	1,425	1,250
Downstream			
Energy (Million Kwhrs)	889	656	534
At Site			
Firm Capacity	$8,160,000	$6,720,000	$6,000,000
	6,800,000	5,700,000	5,000,000
	$14,960,000	$12,420,000	$11,000,000
Downstream			
Energy	$2,667,000	$1,968,000	$1,602,000
	$17,627,000	$14,388,000	$12,602,000
Cost	$135 million	$135 million	$130 million

Note: Capacity and energy at site were estimated at $24.00 per kilowatt and 4.0 mills per kilowatthour, respectively.

Energy at downstream sites was estimated at 3.0 mills per kilowatt-hour.

A series of operation studies was performed for the three main storage sites to determine the firm energy that could be produced during the critical period. The results of these studies were as follows:

Site	Normal water surface elevation feet	Active storage acre-feet	Drawdown in percent of maximum gross head percent	Annual firm energy MWH	Installed capacity MW
Big Rapids	910	1,540,000	13	514,000	110
Dickey	910	2,250,000	10	719,000	150
Rankin Rapids	860	2,800,000	12	958,000	200

A comparable drawdown at the Dickey site to 12 percent of the maximum gross head would provide 750,000 MWH of firm energy annually.

Integration studies of the tidal and St. John plants were made on an hourly basis using the results from computer runs for 500, 700, and 900 MW tidal installation when operated to meet 1-hour peaking periods. Several studies were performed for each size of tidal installation. In each of these studies a firm energy requirement was assumed to determine tha amount of tidal energy that could be used within the requirement and also to determine how much energy from St. John developments would be required to satisfy the remaining assumed firm energy load. From these results, estimates were made of installed capacities that fully utilized the firm energy available from St. John developments.

The coordinated operation studies indicate that firm energy available from upper St. John developments is not adequate to fully integrate all the tidal offpeak energy into a firm energy pattern. More integration would require the inclusion of other hydrodevelopments such as the potential Mactaquac development on the lower St. John. Another possibility indicates that the length of the peaking period for the tidal plant could be varied for different tide ranges thus changing the offpeak tidal energy generation. For example, during neap tide ranges the peaking capability would be provided for periods of one hour or less. The length of the peaking capability could then be increased with higher tide ranges. The tidal plant could then supply the portion of the peak load best utilizing its output which is highly dependable and predictable. Other plants in coordination could then be shifted to supply the remaining peak energy demand.

Reregulation

A hydroelectric power plant operating to serve a load with sharp peak characteristics requires a reservoir downstream to reregulate the flows so as to obtain as near continuous flow as possible. The reregulating reservoir must be placed downstream from the main reservoir and must have sufficient storage to accomodate the large influxes of water so they can be released in a uniform fashion. A power plant such as Dickey on the Upper St. John River would require a reregulating reservoir for its operation on a peaking power basis. This reregulating reservoir can be located at the Lincoln School site; however, the capacity of the reservoir could not be as great as the Lincoln School arrangement described in the IJC's report. Under the plan herein proposed the water level for the Lincoln School reservoir would be restricted to an elevation that would not enroach on the tailwater from Dickey power plant. However, sufficient reservoir capacity at Lincoln School must be provided for the necessary reregulation of water release from Dickey.

Further studies are required as to the precise location of Dickey power plant site and the contemplated discharge from this plant. No cost estimates were included in the present study to cover the cost of an installation of the reregulating reservoir. Unquestionably such a reservoir will be necessary in the project plan. It is expected that power revenues from the reregulating reservoir will support the cost thereof. Hence, estimates were made.

Preliminary studies were made to determine the amounts of storage that would be required to provide daily and monthly reregulation. Following is the results of these studies:

St. John Development	Reregulation Storage in Acre-Feet Daily regulation	Monthly regulation
Big Rapids	4,000	12,500
Dickey	5,000	15,500
Rankin Rapids	7,000	21,000

The following table summarizes the St. John Developments.

Summary of Integrated Operation of Tidal Plant
and St. John Developments

Development	St. John Development installed capacity			Energy for month of October			
	Capacity for integrated firm energy	Capacity to firm tidal capability	Total installed capacity	Integrated firm energy	Energy from firmed tidal capability 1.0 hr. peak	Total firm energy	Remaining available offpeak tidal energy
	MW	MW	MW	MWH	MWH	MWH	MWH
Big Rapids alone	110	0	110	44,800	0	44,800	0
with 500 MW Tidal	190	170	360	78,900	15,500	94,400	80,300
with 700 MW Tidal	180	280	460	76,500	21,700	98,200	86,800
with 900 MW Tidal	170	410	580	72,400	27,900	100,300	89,300
Dickey alone	150	0	150	62,600	0	62,600	0
with 500 MW Tidal	260	170	430	110,000	15,500	125,500	67,100
with 700 MW Tidal	250	280	530	106,300	21,700	128,000	74,900
with 900 MW Tidal	240	410	650	101,900	27,900	129,800	77,700
with 1000 MW Tidal	240	480	730	106,300	30,000	136,300	82,000
Rankin Rapids alone	200	0	200	83,400	0	83,400	0
with 500 MW Tidal	340	170	510	144,300	15,500	159,800	53,600
with 700 MW Tidal	320	280	600	138,300	21,700	160,000	63,700
with 900 MW Tidal	310	410	720	133,800	27,900	161,700	66,600

Downstream Power Benefits

Considerable benefits in Canada would accure to existing and potential downstream hydrodevelopments by providing storage on the Upper St. John. An estimate of these benefits was obtained from studies made of the St. John River by the St. John River Board of the New Brunswick Electric Power Commission. The objective of those studies was to evaluate and plan the sequence of power developments in New Brunswick and Nova Scotia. For that investigation, several series of studies were performed, with and without a tidal development.

To obtain estimates of downstream benefits resulting from development of the Big Rapids or Dickey sites, the values obtained by the St. John River Board for Rankin Rapids were proportioned on the basis of regulated annual flows. The benefits for Rankin Rapids were based on the assumption that Rankin Rapids would begin operation in 1968 and the tidal plant would go into operation in 1970. The following table shows the estimated downstream benefits for the Upper St. John development from 1970 to 1980. After 1980 the benefits are constant.

Estimate of Downstream Benefit in Millions of KWH

Year	Upper St. John Development		
	Rankin Rapids	Dickey	Big Rapids
1970	+409.7	+299.0	+243.3
1971	+308.6	+225.2	+183.3
1972	+784.0	+572.1	+465.6
1973	+774.4	+565.1	+459.9
1974	+961.7	+701.8	+571.2
1975	+849.6	+620.0	+504.6
1976	+556.9	+406.4	+330.7
1977	+1012.5	+748.8	+601.3
1978	+1004.6	+733.0	+596.6
1979	+1006.5	+734.4	+597.8
1980	+889.1	+656.1	+534.0

Load and Resources Study

The marketing area visualized for adequate utilization of the potential power from Passamaquoddy and the St. John River embraces the New England States, Upper New York State, and the Canadian Provinces of New Brunswick and Nova Scotia.

The electric power capacity of the electric power utilities operating in this area was 13.3 million kilowatts in 1960, of which 10.0 million kilowatts were from thermal plants. The Federal Power Commission and the New Brunswick Electric Power Commission estimated that the power requirements in 1980 would be 36,000,000 kilowatts. To meet these forecasts, 23,000,000 kilowatts of new capacity would be required.

The states of Maine, New Hampshire and Vermont are supplied with significant amounts of hydro and thermal generation. Massachusetts, Connecticut and Rhode Island are predominantly steam with hydro producing a negligible part of the supply. In view of the resources of the area, it is anticipated that future developments of Maine, Vermont and New Hampshire will continue with hydro and steam and these states would provide a market for the output development of proposed power plants on the Upper St. John River. The upstream storage provided by these developments would provide substantial downstream benefits on the Lower St. John River in Canada at the plants of the New Brunswick Electric Power Commission.

Based on present planning and practice in the utility industry it appears that the future load requirements of Massachusetts, Connecticut and Rhode Island will be met by generating units of large size, possibly in excess of 500 MW. This trend can be seen by the plans of the Boston Edison Co. to install a 340 MW thermal plant at its "L" St. Station. With the increase in the number of large capacity units, which can reasonably be expected, it will be desirable to obtain peaking capacity from sources such as Passamaquoddy and the Upper St. John River.

The large thermal generating units are essentially fixed load units with no flexibility. River hydroelectric powerplants are inherently flexible and provide excellent sources of peaking capacity. The Passamaquoddy Tidal development as presently conceived with a two pool arrangement could ideally provide substantial peaking capacity, and in addition to possessing the virtues of a river hydroelectric powerplant, it would be perpetual, dependable, fully predictable and suffer no periods of drought.

The type of peaking capacity that can be developed and delivered by suitable transmission system from Passamaquoddy would be readily marketable in the New England States and New Brunswick areas when the power could be made available.

The Federal Power Commission's Task Group of the New York Regional Office, Northeastern Regional Advisory Committee, working on the National Power Survey states that:

> "Peaking capacity requirements of New England are met with hydroelectric power and older, less efficient thermal capacity, including gas turbines and diesel units. As the load increases and much of the existing fuel-electric capacity is retired, new sources of peaking capacity will have to be developed. Historically speaking, New England has a long record of water power development. Although many of the more favorable sites have been developed, a substantial amount of undeveloped hydroelectric power still remains, principally in Maine. The Task Group has recognized this by including 1,300 megawatts of unidentified peaking hydro power in northern Maine as part of the Area power supply in 1975. In addition they have identified three pumped-storage installations of 300 megawatts each. Thus, by 1980 a total of approximately 3,500 megawatts of hydroelectric may be expected to be available for serving the electric utility load in New England."

Power Costs

In order to appraise the power market for the area to be served by the Passamaquoddy-Upper St. John River development, the Committee made a complete listing of all powerplants operating in New England during 1961. The results of this study which is tabulated in the Appendix are shown as average costs of capacity and energy on Figure 10. Also shown is the estimated cost of producing power from the Passamaquoddy-St. John River development at an interest rate of 2-7/8 percent. This clearly demonstrates the immediate market for these power developments, since power will be produced at $24 per KW of capacity and energy at 4.0 mills per KWH. Whereas 1961 actual costs were $26 per KW for capacity and 6.36 mills per KWH for energy. These costs are at the point of generation in both cases.

Also, the power values used herein for estimating power benefits for near future construction of alternate privately financed modern high efficiency thermal generation are: (1) Maine area--$31.20 per KW per year and 5.0 mills per KWH, and (2) remaining New England area $26.15 per KW per year and 3.2 mills per KWH.

The immediate development of power at the Passamaquoddy Tidal project integrated with the Upper St. John, Dickey and modified Lincoln School projects would provide Maine, New England and New Brunswick with a power supply at about 25 percent less than

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POWER COST AT PLANT
(No transmission)

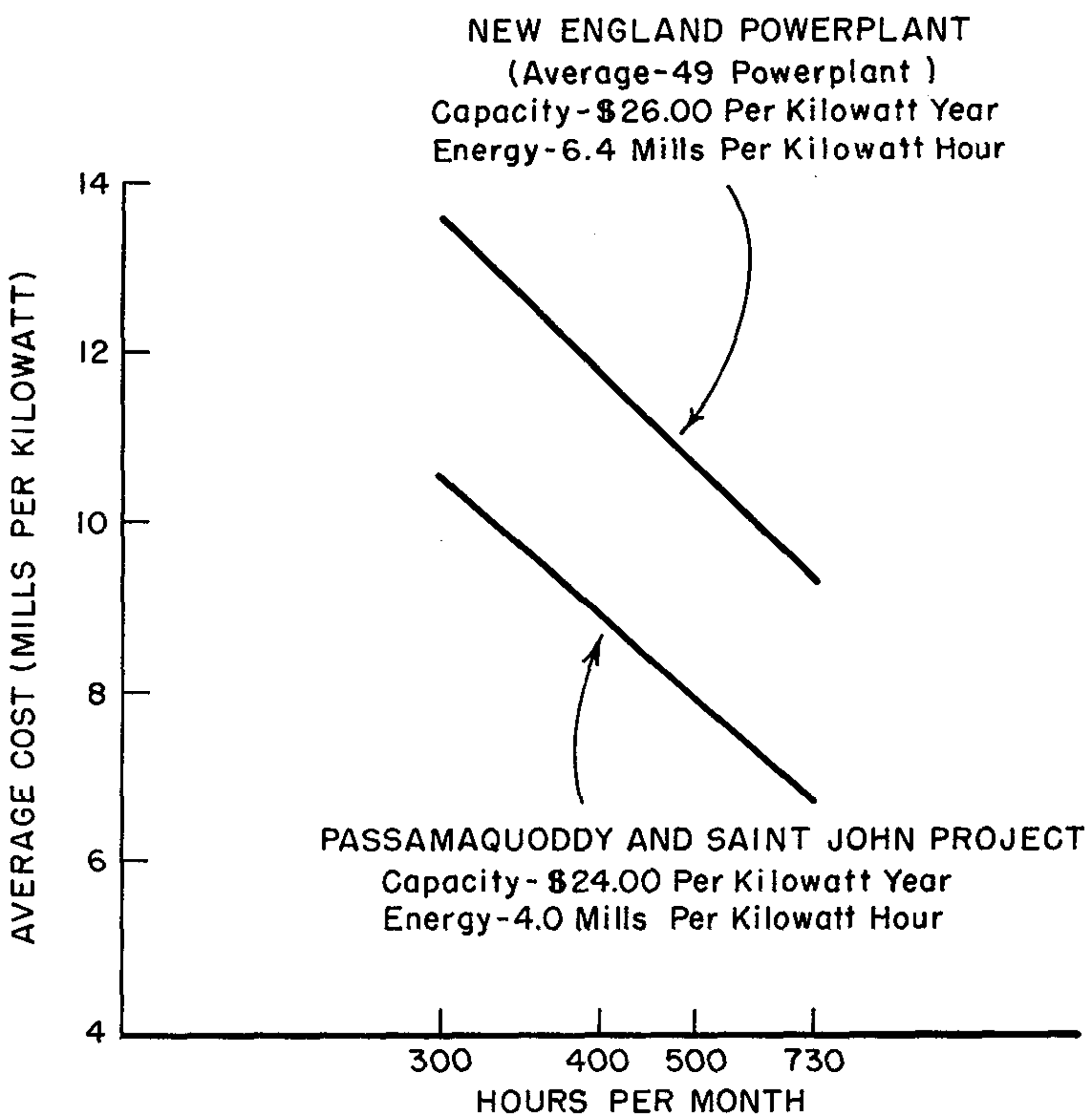


FIGURE 10

present cost. This would contribute greatly to the development of the area and the nation.

The construction of these projects would also provide tremendous opportunities for employment and contribute national recreational benefits. The proposed plan would also forever protect the recreational values of the Allagash River.

APPENDIX I

Details of Computer Program

Computer Studies

To perform the repetitious computations required to study the effect of the tidal cycle on a two-pool operation, an electronic computer program was developed by the Office of the Chief Engineer of the Bureau of Reclamation. The program was coded for an IBM 7090 electronic computer having eight magnetic tape units. The program requires approximately 18,000 words of core storage. The FORTRAN II programing language was used for compilation. The amount of computer time required for processing a monthly tide cycle is dependent upon the assumed powerplant installed capacity. The curve shown in Figure 11 shows the approximate time required for processing a monthly tide cycle with a 1-hour peaking period.

The computer program is comprised of the main program plus 13 subroutines. A brief description of each follows:

1. The main program controls the flow of the computation through the appropriate Phase, either A, B, C, or D.

2. Subroutine DATARD is utilized at the beginning of computations to read in the study constants, such as the beginning hour for a study, length of a study in hours, powerplant capacity, duration of peaking period, etc.

3. Subroutine REDTAB is a read-in routine to load eight tables representing data taken from curves, such as head vs. generation, content vs. elevation of pools, etc.

4. Subroutine STIDE is used at the start of each phase to compute the ocean elevations necessary for the pool operations. A prediction equation is used for the calculation of the tides.

5. Subroutine TABLE is a table-lookup procedure which incorporates an interpolation routine.

6. Subroutine FAMILY is a more sophisticated table-lookup procedure for tables representing a family of curves. Two arguments are necessary for this routine.

7. Subroutine EQTNS is used to solve equations to determine net heads on the turbines, heads on the filling gates, heads on the emptying gates, etc. The appropriate equations are solved by the use of a program switch which is dependent upon the condition of the pools, high pool filling, low pool emptying, etc.

8. Subroutine PEAK is a portion of the program which controls the logic and computations necessary for power generation during a peaking period. A program switching system is used in this subroutine to adapt the computations to a particular phase, pool conditions, etc.

9. Subroutine DUMP is used for the computation of off-peak or dump generation. The logic and order of computation are controlled in this subroutine by program switches which are dependent on the pool operation status at the end of the peaking generation.

10. Subroutine END provides the logic and calculations necessary to operate the pools properly at the end of a phase.

11. Subroutine SLPED controls the computations necessary for the production of off-peak generation during Phase D.

12. Subroutine SLPE regulates the pool operation in Phase D between the time when generation is stopped and the high pool filling begins.

13. Subroutine SHP provides the logic and computations necessary for filling the high pool at the end of Phase D.

14. Subroutine OUTPUT is used for writing the results and punching cards for use with the electronic plotter.

An explanation of the operating criteria for the pool operation as provided in the program is furnished below.

The program uses four phases, Phases A, B, C, and D, see Figure 2. Phase A covers a period about 24 hours and 50 minutes in length. This phase is used for meeting peaking periods starting between 5.8 and 13 hours after the first high tide. At the start of Phase A, the low pool is emptied and the high pool is kept full until the peaking period starts. After the end of the peaking period, all possible off-peak energy is produced until the end of Phase A. A decision is then made to determine if Phase A is repeated or if Phase B is entered.

Phase B is an intervening step that is included to get from a Phase A to a Phase C type operation. In general, the phases would be performed as follows: -A-A-B-D-C-D-C-D-C-A-A-, etc. Phase B is similar to the start of Phase A and allows for meeting peaking periods beginning between 5.0 and 5.8 hours after the high tide.

Phase C is entered with the high pool full and the low pool empty. This phase is used for meeting peaking periods starting between 0.6 and 5.0 hours after the high tide. The 0.6 is derived from the consideration that each phase starts and ends when the high pool is filled, which is about 0.6 hour after the time of the high tide.

Phase D is an intervening step that is entered into from either Phase B or C. Phase D allows the generation of off-peak energy and provides for emptying the low pool prior to the start of a Phase C type operation.

The general format of the computations is that new high and low pool elevations are estimated based on the elevations at the two preceding time intervals. The pool and ocean elevations are then used to compute discharges through the powerplant and/or filling or emptying gates. These discharges are then converted to volumes which are used to adjust the contents of the two pools. Content versus elevation tables are then used to determine the revised elevations of the pools. These determined elevations are then compared with the estimated elevations for that time period. If the two sets of elevations are within the limits of $\pm$ 0.02 foot, the program proceeds to the next time interval.

The computations in the program are made for 3-minute time intervals. This short time interval is necessary because of the rapid change in pool elevations possible with the large installed powerplant capacities to be studied. The short time interval does, however, simplify the determination of the time when the pool elevations coincide with the ocean elevations. At these points the computations are changed to allow for emptying and filling of the pools.

The program was developed to allow for the study of peaking periods varying up to 4 hours in length. This variable length of peaking period complicates the program. In Phase A, for example, the peaking generation can begin: (1) when the low pool is emptying, (2) when the low pool is emptied, (3) when the high pool is filling additionally with the second high tide, or (4) when this additional filling is completed.

This allows the possibility of any one of four different computations being performed when the peaking starts. Depending upon the length of the peaking period, a period starting when the low pool has been emptied can end when: (1) the high pool is emptying into the low pool, (2) when the high pool is obtaining additional filling from the ocean, (3) when the additional filling is completed and the only discharge is again from the high pool to the low pool, or (4) when the low pool is emptying to the ocean. The program was devised to allow the computations to follow through these various routes and combinations until the computations can become similar again in the off-peak generation during the second tidal cycle.

The minimum head selected for the operation of the turbines was 6 feet. This minimum head provides for the use of specific control points in each of the phases. In the various subphases the greatest possible off-peak energy is produced without going below the minimum head. At each time interval, the program checks to determine whether the actual head is below the minimum permissible head. If the actual head is less than 6 feet, turbines are dropped off, energy production reduced, and the computations are repeated from the start of the subphases. At the control points at the end of the subphases, the program checks to determine if additional head above this minimum is available. If so, turbines are added on, energy production increased, and the computations are repeated from the start of the subphase. The number of turbines operating at the end of the subphases is stored in the computer and then used for the first trial when a similar subphase is entered again. These computations reflect a physical operation where a constant number of turbines would be operated during each off-peak period.

Somewhat similar computations are performed to insure that the maximum peaking capability is obtained. In this case, the program performs computations to check if the actual head is below the minimum head, or if more turbines are required to meet a "trial peaking capability" than would be available with the installed capacity being studied. If either of these occurrences is indicated, the program reduces the "trial peaking capability" and repeats the computations from the start of the peaking period. At the end of the peaking period, the program checks to determine if all turbines are being used to meet the "trial peaking capability." If not, the trial value is increased and computations are repeated from the start of the peaking period. The peaking computations are stopped when the check at the end of the period indicates all turbines are being used or that the last adjustment of the trial value was a decrease. The trial value at the end of the peaking period, having been adjusted to the actual capability for that period, is then stored in the computer for use in the first trial in the next peaking period. These computations reflect a physical operation where there would be a continual increase in the number of turbines operating during a peaking period.

To insure that the pools are emptied or filled as much as possible, certain other provisions are included in the program. In Phase A and the last time through Phase C, for example, the minimum ocean elevations are checked. If the low tide of a neap tide is occurring, off-peak generation is stopped and the high pool is filled to the highest elevation possible. Similarly, during Phase D in a neap tide, generation is limited to insure that the low pool is emptied to an elevation close to the minimum ocean elevation.

The discharge versus head tables that are used for the filling and emptying gates include allowances for the head losses through the gates and channels. Separate tables are included in the program to allow computation of head losses in the approach channel to and tail race channel from the powerplant. An equation is used to compute head losses in the low pool due to slope of water surface. The equation is, however, considered to be only a reasonable approximation of the loss due to water surface slope in the low pool. A more accurate value could be obtained by making detailed routings of the movement of water in the low pool. This was not believed to be necessary for the present studies to evaluate the Passamaquoddy Tidal Power Project for peaking capabilities.

The computer program output gives ocean and pool elevations, net turbine head, weighted turbine head, and powerplant output. A sample of the output is shown in Figure 13. This information was used to develop curves showing peaking capability versus percent time, dependable capability versus installed capacity, and peak and off-peak generation versus installed capacity. The output can also be punched in cards so that a plotting machine can graphically plot the elevations and plant output for selected installed capacities. A sample plot for a 200 hour period showing both a neap and spring tide is shown in Figure 7.

APPENDIX II

Tabulation of Power Cost

in New England

Power Costs in New England

The attached tabulation is based on the estimated Federal Power Commission procedures for determining fixed cost of powerplants and includes cost of money, depreciation, interim replacements, insurance, Federal income taxes, additional miscellaneous taxes, and state and local taxes. The average figures for these were obtained from Federal Power Commission data. Other information shown was taken from the following publications:

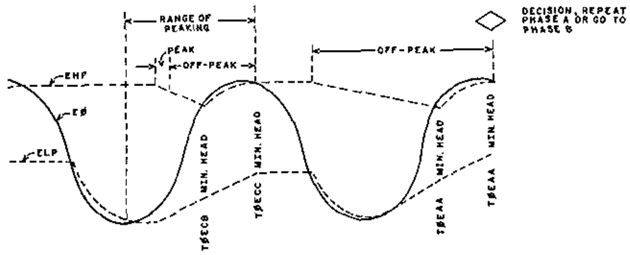
> Hydroelectric Plant Construction Cost And Annual Production Expenses - Fourth Annual Supplement, 1960
>
> Steam-Electric Plant Construction Cost And Annual Production Expenses - Fourteenth Annual Supplement, 1961

Power Costs in New England *

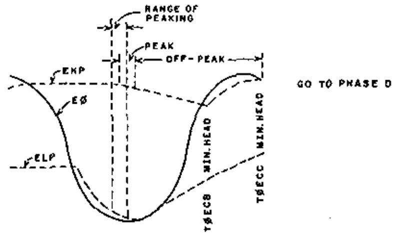
Powerplant - Capacity	Cost $/Kw	Fixed Charge %	Fixed * Charge $/Kw	Production Costs Mills/Kwh	Year Installed	Plant Factor %
Maine						
Graham (T) - 28,000 Kw	170	13.0	$22.10	7.4	1954	51
Mason (T) - 139,000 Kw	169	10.5	17.50	6.4	1941	26
Wyman (T) - 88,000 Kw	219	10.5	23.00	4.8	1957	86
Caribou (T) - 19,000 Kw	209	11.3	23.60	9.3	1950	59
Gulf Island (H) - 19,000 Kw	249	10.5	26.20	1.5	1926	79
Indian Pond (H) - 76,000 Kw	219	10.5	23.00	0.5	1954	34
Skelton (H) - 16,000 Kw	450	10.5	47.30	0.5	1948	79
Williams (H) - 13,000 Kw	242	10.5	25.40	0.6	1939	87
Wyman (H) - 72,000 Kw	196	10.5	20.60	0.3	1930	58
New Hampshire						
Merrimack (T) - 113,000 Kw	197	12.5	24.70	4.3	1960	74
Schiller (T) - 190,000 Kw	180	12.5	22.60	5.8	1949	48
Amoskeag (H) - 16,000 Kw	140	12.5	17.65	0.8	1922	72
Smith (H) - 15,000 Kw	273	12.5	34.20	0.5	1948	88
Comerford (H) - 140,000 Kw	112	13.2	23.50	1.1	1930	22
Moore (H) - 140,000 Kw	216	13.2	28.60	1.5	1957	19
Wilder (H) - 32,000 Kw	397	13.2	52.60	1.0	1950	45
Vermont						
Lake Front (T) - 30,000 Kw				9.8	1954	
Rutland (T) - 18,000 Kw	176	13.2	23.30	22.5	1951	27
Clarks Falls (H) - 3,000 Kw	294	13.2	36.80	1.0	1937	57
Milton (H) - 6,000 Kw	118	13.2	15.56	1.3	1928	66
Peterson (H) - 5,000 Kw	261	13.2	34.60	0.7	1948	52
Weybridge (H) - 3,000 Kw	419	13.2	55.30	1.2	1951	50
Bellows Falls (H) - 40,000 Kw	175	13.2	23.15	0.8	1928	62
Harriman (H) - 33,000 Kw	274	13.2	36.20	1.2	1924	44

Power Costs in New England *

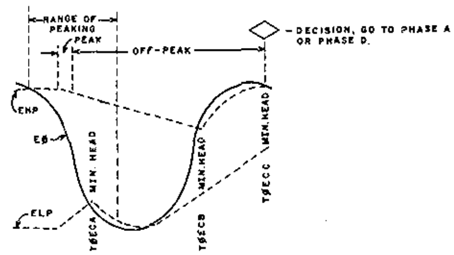
Powerplant - Capacity	Cost $/Kw	Fixed Charge %	Fixed * Charge $/Kw	Production Costs Mills/Kwh	Year Installed	Plant Factor %
Massachusetts						
Edgar (T) - 457,000 Kw	156	15.0	$23.40	6.1	1925	46
"L" Street (T) - 153,000 Kw	162	15.0	24.30	10.0	1906 - 1919	42
Mystic (T) - 618,000 Kw	161	14.4	23.20	4.8	1943	-
Mt. Tom (T) - 125,000 Kw	189	14.4	27.30	3.9	1960	95
Somerset (T) - 290,000 Kw	170	11.5	19.50	4.9	1925	66
Cannon St. (T) - 137,000 Kw	128	14.4	18.30	6.7	1916	46
Salem Harbor (T) - 319,000 Kw	179	13.2	23.80	4.3	1952	74
W. Water St. (T) - W. Springfield (T) - 209,000 Kw	159	14.4	22.90	4.4	1949	66
Sherman (H) - 7,000 Kw	190	13.2	25.10	0.6	1927	51
Connecticut						
Danielson (T) - 12,000 Kw	229	12.4	28.70	19.0	1953	9
Devon (T) - 479,000 Kw	137	12.4	17.05	5.0	1923	52
Monville (T) - 176,000 Kw	167	12.4	21.90	5.4	1919	52
Norwalk Harbor (T) - 15,000 Kw	150	12.4	18.70	3.9	1919 - 1924	82
Thompsonville (T) - 12,000 Kw	239	12.4	29.80	54.0	1953	33
Housatonia Ave. (T) - 20,000 Kw	129	12.4	16.10	14.0	1953	46
Middletown (T) - 166,000 Kw	192	11.6	22.10	4.1	1954	88
South Meadow (T) - 215,000 Kw	140	11.6	16.30	9.5	1921	
Bridgeport Harbor (T) - 225,000 Kw	190	13.5	21.90	4.3	1957	
English (T) - 135,000 Kw	185	13.5	21.40	8.9	1929	44
Steel Point (T) - 146,000 Kw	163	13.5	18.90	8.9	1923	39
Rocky River (H) - 31,000 Kw	208	12.4	25.80	27.7	1929	3
Shepang (H) - 37,000 Kw	483	12.4	60.20	1.1	1955	38
Stevenson (H) - 30,000 Kw	201	12.4	25.10	0.3	1919	36
Rhode Island						
Manchester St. (T) - 147,000 Kw	165	11.6	19.10	7.2	1923	52
South Street (T) - 213,000 Kw	171	11.6	19.90	7.3	1909 - 1912	40
			Average 26.00 /Kw	6.36/mills		



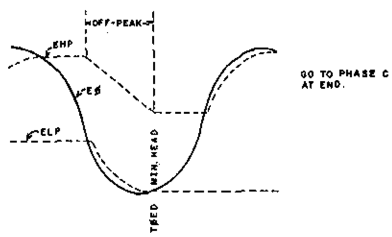
PHASE A



PHASE B



PHASE C



PHASE D

NOTES: EHP = ELEVATION OF THE HIGH POOL
EØ = ELEVATION OF THE OCEAN
ELP = ELEVATION OF THE LOW POOL
TØECA, ETC. = NUMBER OF TURBINES OPERATING AT THE END OF THE VARIOUS SUBPHASES.

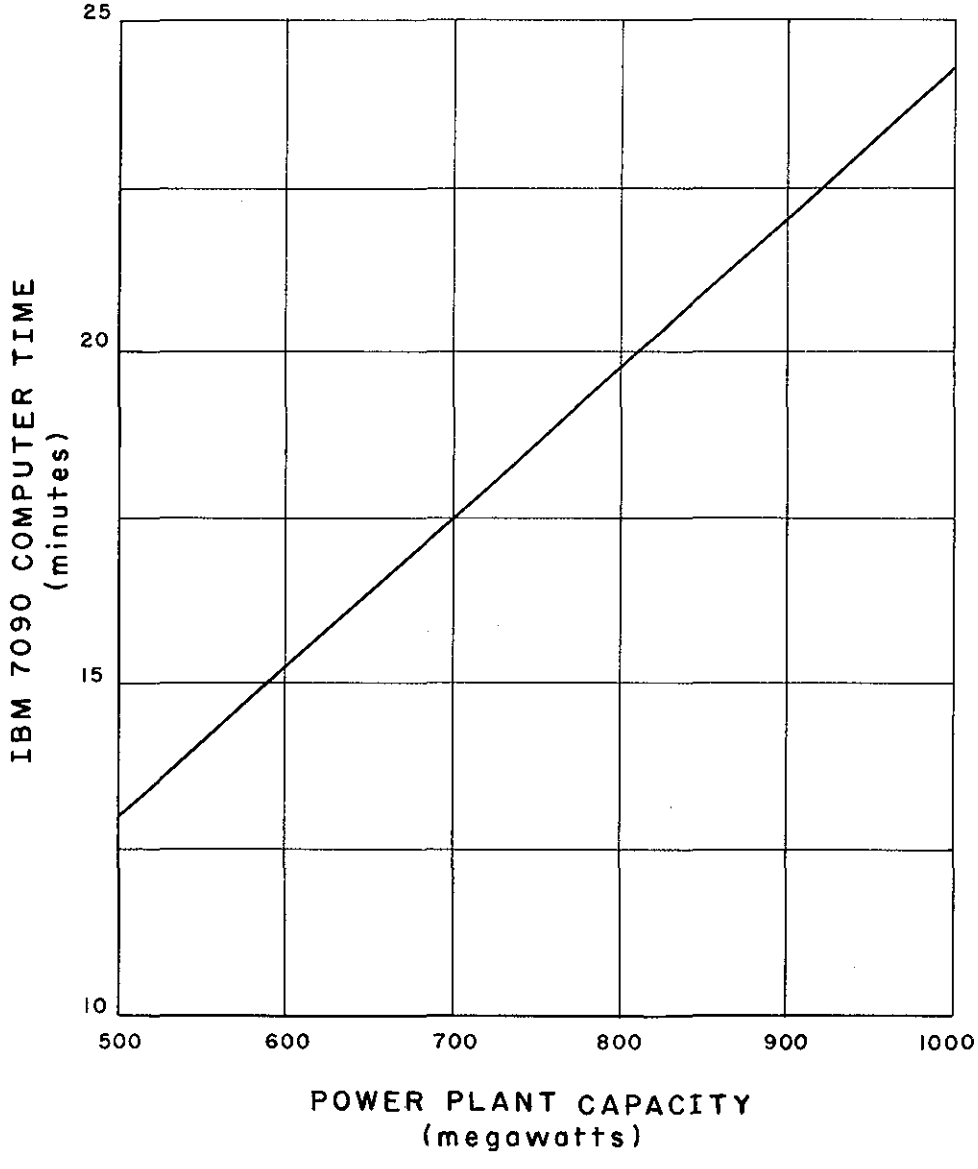
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PASSAMAQUODDY TIDAL POWER PROJECT
POOL OPERATING CRITERIA
IN PHASES A, B, C, AND D

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

MAY 14, 1963

FIGURE 11



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PASSAMAQUODDY TIDAL POWER PROJECT

TIME VS. POWER PLANT SIZE
1.0 HOUR PEAKING PERIOD
30 DAY STUDY

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO — MAY 14, 1963

FIGURE 12

CREATED BY ACT OF CONGRESS in 1849, the Department of the Interior is responsible for a wide variety of programs concerned with the management, conservation, and wise development of America's natural resources. For this reason it often is described as the "Department of Natural Resources."

Through a score of bureaus and offices the Department has responsibility for the use and management of millions of acres of federally owned lands; administers mining and mineral leasing on a sizable area of additional lands; irrigates reclaimed lands in the West; manages giant hydro-electric power systems; administers grazing and forestry programs on federally owned range and commercial forest lands; protects fish and wildlife resources; provides for conservation and development of outdoor recreation opportunities on a nationwide scale; conserves hundreds of vital scenic, historic, and park areas; conducts geologic research and surveys; encourages mineral exploration and conducts mineral research; promotes mine safety; conducts saline water research; administers oil import programs; operates helium plants and the Alaska Railroad; is responsible for the welfare of many thousands of people in the territories of the United States and exercises trusteeship for the well-being of additional hundreds of thousands of Indians, Aleuts, and Eskimos, as well as being charged with resource management of millions of acres of Indian-owned lands.

In its assigned function as the Nation's principal natural resource agency, the Department of the Interior bears a special obligation to assure that our expendable resources are conserved, that renewable resources are managed to produce optimum yields, and that all resources contribute their full measure to the progress, prosperity, and security of America, now and in the future.

INTERIOR--PORTLAND, OREGON

PASSAMAQUODDY TIDAL POWER STUDIES

30 DAYS MAXIMUM GATE 90 TURBINES DURATION OF PEAKING PERIOD = 1.00 HOURS

TIME (HOURS)	OCEAN ELEVATION	LOW POOL ELEVATION	HIGH POOL ELEVATION	NET TURBINE HEAD	WEIGHTED HEAD	NUMBER OF TURBINES OPERATING	POWER PLANT GENERATION (MW)	POWER PLANT ENERGY (MWH)	CUMULATIVE PEAK ENERGY (GWH)	CUMULATIVE DUMP ENERGY (GWH)
6963.90	11.43	11.76	24.29	12.24	9.80	66	586.615	29.331	12.290	54.332
6964.00	11.70	11.87	24.20	12.02	9.80	66	569.699	28.485	12.290	54.390
6964.10	11.99	12.03	24.11	11.81	9.80	66	553.940	27.697	12.290	54.446
6964.20	12.30	12.22	24.03	11.47	9.80	66	527.955	26.398	12.290	54.499
6964.30	12.63	12.47	23.94	11.16	9.80	66	504.176	25.209	12.290	54.550
6964.40	12.98	12.65	23.85	10.86	9.80	66	480.969	24.048	12.290	54.599
6964.50	13.35	12.89	23.77	10.56	9.80	66	458.176	22.909	12.290	54.645
6964.60	13.74	13.06	23.68	10.28	9.80	66	436.613	21.831	12.290	54.689
6964.70	14.14	13.30	23.60	10.00	9.80	66	415.219	20.761	12.290	54.731
6964.80	14.56	13.46	23.52	9.73	9.80	66	394.421	19.721	12.290	54.771
6964.90	14.99	13.70	23.44	9.46	9.80	66	373.831	18.692	12.290	54.809
6965.00	15.43	13.85	23.36	9.20	9.80	66	353.937	17.697	12.290	54.845
6965.10	15.88	14.06	23.29	8.95	9.80	66	334.870	16.744	12.290	54.879
6965.20	16.34	14.24	23.21	8.68	9.80	66	313.920	15.696	12.290	54.911
6965.30	16.81	14.43	23.14	8.44	9.80	66	296.043	14.802	12.290	54.941
6965.40	17.29	14.59	23.07	8.19	9.80	66	276.453	13.823	12.290	54.969
6965.50	17.78	14.76	23.00	7.99	9.80	66	261.222	13.061	12.290	54.996
6965.60	18.26	14.93	22.93	7.74	9.80	66	241.802	12.090	12.290	55.020
6965.70	18.76	15.08	22.86	7.54	9.80	66	226.462	11.323	12.290	55.043
6965.80	19.25	15.23	22.79	7.31	9.80	66	209.491	10.475	12.290	55.065
6965.90	19.75	15.37	22.72	7.13	9.80	66	195.437	9.772	12.290	55.085
6966.00	20.25	15.51	22.66	6.92	9.80	66	179.008	8.950	12.290	55.103
6966.10	20.75	15.64	22.63	6.78	9.80	66	168.496	8.425	12.290	55.120
6966.20	21.25	15.76	22.54	6.59	9.80	66	154.338	7.717	12.290	55.136
6966.30	21.75	15.89	22.53	6.45	9.80	66	143.698	7.185	12.290	55.150
6966.40	22.24	15.98	22.44	6.30	9.80	66	131.639	6.582	12.290	55.164
6966.50	22.73	16.02	22.46	0.	9.80	0	0.	0.	12.290	55.170
6966.60	23.22	16.02	22.54	0.	9.80	0	0.	0.	12.290	55.170
6966.70	23.70	16.02	22.66	0.	9.80	0	0.	0.	12.290	55.170
6966.80	24.17	16.02	22.77	0.	9.80	0	0.	0.	12.290	55.170
6966.90	24.64	16.02	22.96	0.	9.80	0	0.	0.	12.290	55.170
6967.00	25.09	16.02	23.12	0.	9.80	0	0.	0.	12.290	55.170
6967.10	25.54	16.02	23.29	0.	9.80	0	0.	0.	12.290	55.170
6967.20	25.97	16.02	23.50	0.	9.80	0	0.	0.	12.290	55.170
6967.30	26.39	16.02	23.70	0.	9.80	0	0.	0.	12.290	55.170
6967.40	26.79	16.02	23.92	0.	9.80	0	0.	0.	12.290	55.170
6967.50	27.18	16.02	24.14	0.	9.80	0	0.	0.	12.290	55.170
6967.60	27.55	16.02	24.36	0.	9.80	0	0.	0.	12.290	55.170
6967.70	27.91	16.02	24.58	0.	9.80	0	0.	0.	12.290	55.170
6967.80	28.24	16.02	24.80	0.	9.80	0	0.	0.	12.290	55.170

FIGURE 13